ESR LINE WIDTH OF CONDUCTION ELECTRONS IN P\textsuperscript{+} ION IMPLANTED Si

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ABSTRACT

In order to investigate the nature of lattice imperfections remaining after annealing, ESR due to conduction electrons and electrical measurements are carried out in parallel with a successive layer removal for P\textsuperscript{+} ion-implanted Si annealed at above 600°C. The similar experiments are done for P-diffused Si with various diffusion depths and samples implanted with Ne\textsuperscript{+} ion into the P\textsuperscript{+} ion-implanted Si annealed at sufficiently high temperature for comparison. As a result, the following interesting results are found: (1) ESR line width (\(\Delta H\)) for samples which have a large gradient of a carrier density does not depend on a carrier density in contrast with those for bulk samples. (2) \(\Delta H\) depends sensitively on some imperfections remaining after annealing the sample damaged heavily by ion implantation with high doses and broadens largely even when those imperfections do not have an appreciable influence on a carrier density and mobility. (3) On the other hand, point defects produced by ion implantation with low doses which make carrier density decrease have no influence on \(\Delta H\). Such an imperfection broadening \(\Delta H\) appears to be random strain due to dislocation loops which have been observed by electron microscope.
INTRODUCTION

The investigation on the nature of lattice imperfections in ion-implanted materials remaining after annealing is important in connection with a device application. In the present work, the ESR method is applied to the problem. The sample used is Si implanted with P⁺ ion. The ESR signal with g-value of 2.0055 from lattice defects produced by ion implantation disappears after annealing at above 600°C[1], then the Lorentzian type ESR signal with g-value of 1.9989 from conduction electrons is newly observed[2]. The variations of the line width (δH) of the ESR signal with a successive layer removal are investigated. Electrical measurements are also carried out at the same time. From the results, the nature of the ESR signal of conduction electrons for ion-implanted samples is found to be different from that for bulk materials as reported previously by present authors [2].

In order to clarify the origin of the difference, the ESR and electrical measurements are carried out for Si wafers diffused with P under various diffusion conditions which have a high donor density only in the surface layer as in the ion-implanted sample. Similar experiments are also done for two kinds of samples implanted with Ne⁺ ion at low and high doses, respectively, into the P⁺ ion-implanted Si annealed at sufficiently high temperature.

SAMPLES AND EXPERIMENTALS

The samples used for the present work are shown in Table I. The substrate materials for ion implantation were polished slices of p-type ⟨111⟩ oriented Si with resistivities of 5~30 Ω·cm. The direction of the incident ions is tilted by 7 degrees from the ⟨111⟩ direction to avoid channeling effects. The ion implantations are carried out at room temperature. In order to compare with the results for the ion-implanted samples, Si diffused with P under various diffusion conditions and powdered Si samples having a donor concentration (N_D) of 3.4x10¹⁹ cm⁻³ with various dimensions (a minimum linear dimension is around 1 μm) are also investigated.

The isochronal annealing was performed in vacuum of about 10⁻² Torr, and the annealing time for each stage was 10 min. ESR was measured at liquid nitrogen temperature (≈77 K) by an x-band spectrometer. The method of stripping the surface layer and that of determining the thickness of the layer are described in the previous paper [2]. Electrical measurements were carried out at room temperature.