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Ion Implantation of Te and Sb in GaAs

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Many investigations on ion implantation in silicon have been made and it has been proved that ion implantation is a usuful technique for silicon device fabrication. On the other hand ion implantation in compound semiconductors such as GaAs has not been studied much. To reveal the effect of doping by ion implantation studies on defects and lattice location of implanted ion are of primary importance.

The use of energetic particle channeling is an important technique for determing the lattice location of impurities in single crystals and measuring defect concentration. Angular scans along various channeling directions for both the impurity and the lattice atoms give an important information on lattice location of the impurity. In this paper lattice location of Te and Sb implanted in GaAs and defect concentration are studied by channeling technique as a function of dose and anneal temperature.

Te and Sb ions were implanted at 70 keV at room temperature and 550°C into GaAs crystals with the (111) or the (100) face. The ion beam is tilted at an angle of about 8° to the <111> or <100> axis. Annealing was made in hydrogen atmosphere for 20 minutes. For annealing above 600°C the GaAs surface was coated with SiO_x layer evaporated by electron bombardment. Channeling measurements were carried out on the Van de Graaff of the Ion Implantation Group in Osaka Area. A monoenergetic beam of 1 MeV He ions was used. The backscattered helium ions were measured with a surface barrier detector (~15 keV FWHM resolution) placed about 5 cm from the crystal and 30° from the helium beam axis.

Figures 1 and 2 shows the results of lattice location and defect measurements as afunction of annealing temperature. Figure 1 is for $1x10^{15}/cm^2$ Te room temperature implantation and Figure 2 is for $2x10^{15}/cm^2$ Te room temperature implantation. For annealing below 300°C considerable amount of defects remains unannealed and no attenuation of scattering yield of Te along the <111>and <110> axes was observed as can be seen in Figs. 1 and 2. The percent of displaced atoms are obtained as the area of the damage peak of channeling spectra. The attenuation increases by higher temperature annealing but it was less than about 60%. This suggests that considerable amount of Te occupy random site even after high temperature annealing. Most defects were annealed at 600°C for $1x10^{15}/cm^2$ implantation and at 700°C for $2x10^{16}/cm^2$ implantation.

The angular scans along the <111> , <110> , and <100> axes are shown in Fig. 3.

The sample was implanted with $2x10^{16}/cm^2$ and annealed at 800^oC. The width of the dip of Te for the <111> axis was the same with that of GaAs crystal and for the <110> and the <100> axes the width of Te was different from that of GaAs. These result suggest that about half of Te locates within the <111> atomic row of GaAs but these Te atoms are displaced by several tenths of angstrom from the <110> and the <100> atomic row. In other words Te occupy some site displaced from substitutional or interstitial sites. According to Lindhard average potential model this displacement is about 0.2Å from the <110> axis and 0.3Å from the <100> axis.

For $6x10^{14}/cm^2$,550°C implantation the width of the dip of Te was the same with that of GaAs for the <111>,<110> and <100> axes and about 70% substitutional component of Te was observed.

For Sb implantation the width for Sb was the same with that for GaAs for the three axes and for $8.7x10^{15}$ room temperature implantation 80-90% of Sb occupy substitutional sites after annealing at 900°C.

The conclusion drawn from the study are the following:(1) For high dose room temperature implantation of Te about 50% occupy random site. Te also occupy sites displaced by 0.2~0.3Å from regular lattice site. (2) For $6x10^{14}/cm^2$,550°C implantation of Te about 70% occupy substitutional site. It seems that high temperature implantation is better to obtain high substitutional component (3) Sb shows high substitutional component of 80-90%.

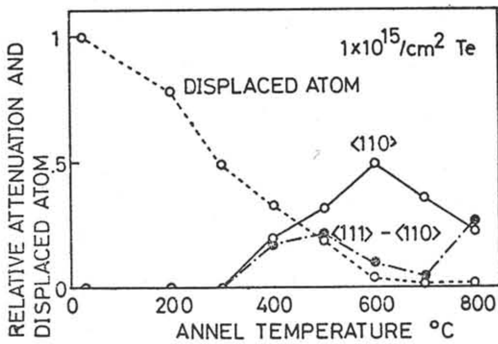

Fig. 1. Relative attenuation of Te scattering yield and displaced atom

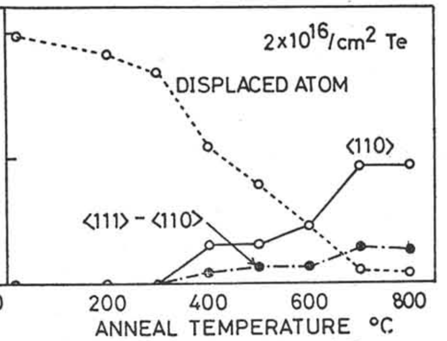

Fig. 2 Relative attenuation of Te scattering yield and displaced atom

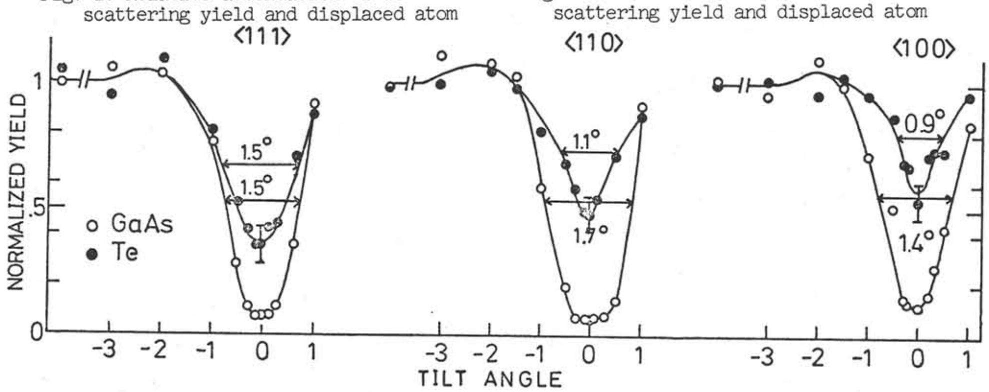

Fig. 3 Angular distribution of scattering yield of GaAs and Te