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BF^{2+} Ion Implantation into Very Low Temperature Si Wafer

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BF_2^+ ions at 30keV were implanted into silicon wafers held at -100°C or room temperature. The recrystallization process of the implanted wafers was examined by RBS and Raman scattering. The value of χ_{min} for wafers implanted at -100 °C and annealed at 600°C is 0.05 being close to that of crystalline Si, while it is 0.08 for the room temperature implantation. The Raman spectrum for the low temperature implantation also exhibits a smaller amount of residual defects than for the room temperature implantation.

1. INTRODUCTION

BF_2^+ molecular ion implantation into Si is used for fabricating a very shallow p^+n junction. The fluorine preamorphization followed by the BF_2^+ implantation is also effective to reduce the junction depth [1]. It is known that a significant part of implanted fluorine is trapped in residual defects even after high temperature annealing [2]. This fluorine trapping is considered to be dependent on the kinetics of defect annealing. Hence, the suppression of spontaneous defect annealing during implantation by keeping a wafer temperature very low will change the recrystallization kinetics and the fluorine trapping process. It is also likely that the remaining lattice defects after the recrystallization are minimized by low temperature implantation as reported for the case of B^+ ion implantation [3].

In this paper, recrystallization and dopant activation processes in BF_2^+ implanted Si at a temperature of -100°C are described. The lowering of the recrystalli-zation temperature, the reduction of lattice defects and the improved fluorine atom distribution profile are demonstrated. Also, the reverse-bias current of the p^+n junctions is examined.

2. EXPERIMENTAL

BF_2^+ ion implantation was carried out at 30keV and a dose of $1x10^{15}cm^{-2}$ for bare p-type Si(100) (ρ=9~12Ωcm) wafers held at room temperature or -100°C. The annealing temper-ature range was 400 to 700°C for 10 min in a dry nitrogen atmosphere. The crystallinity at each annealing step was measured by using Rutherford backscattering (He^+ ion, 2MeV) and Raman scattering spectroscopy. Activation of the impurity was monitored by sheet resistivity. Boron and fluorine in-depth profiles were measured by secondary ion mass spectrometry (SIMS). For the leakage current measurements BF_2^+ ions were implanted into n-well (N_D~$10^{16}cm^{-3}$) at 60keV through a 300Å thermal oxide with a dose of $3x10^{15}cm^{-2}$. The p^+n diode area was changed from 13x20 to 400x400 μm^2.

3. RESULTS AND DISCUSSION

The RBS spectra of BF_2^+ implanted wafers before and after annealing are shown in Fig.1. The spectra are normalized by the random spectrum. The peak signal observed in the aligned spectra for as implanted wafers exhibits the existence of the amorphized layer. The low temperature implantation leads to the higher

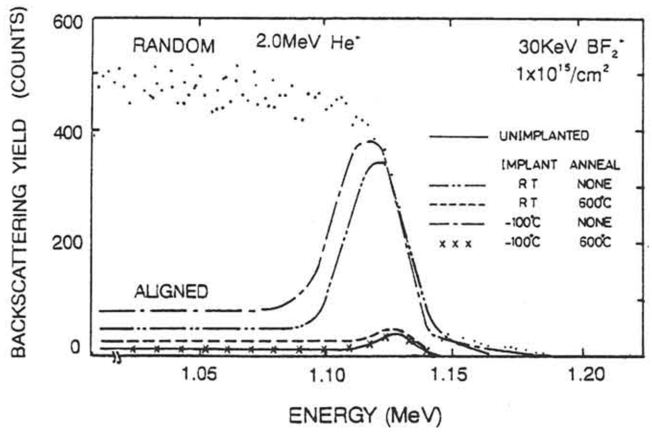


Fig. 1 RBS spectra for room temperature and -100°C implanted samples. The spectrum of the -100°C implanted and annealed wafer coincides with an unimplanted wafer.

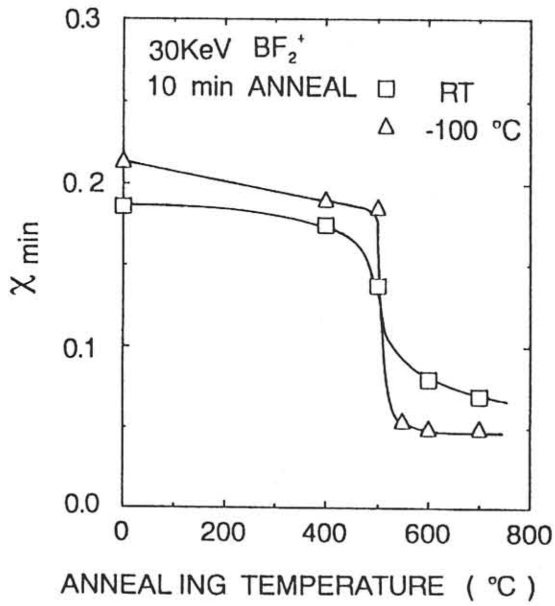


Fig. 2 χ_{min} determined by RBS versus annealing temperature.

backscattering yield of aligned spectrum than the room temperature (RT) implantation. The scattering peak for the -100°C sample is higher and extended deeper into the bulk than the case of the RT implantation. This indicates that the extent of the amorphization in the -100°C sample is more significant than the RT specimen and that the spontaneous annealing is suppressed during the low temperature implantation. After 600°C annealing, the RBS spectrum for the -100°C implantation provides the lower yield than the RT case and coincides with the crystalline Si spectrum, showing the recrystallization of the amorphized layer in the -100°C specimen. Indeed, the χ_{min} value obtained by RBS proves that the low

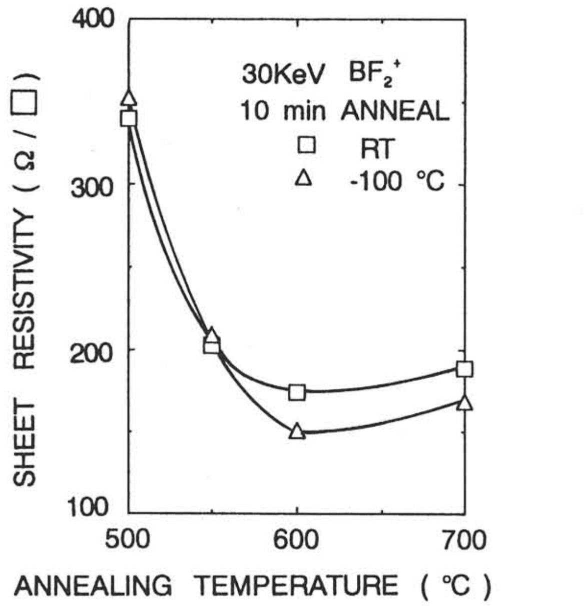
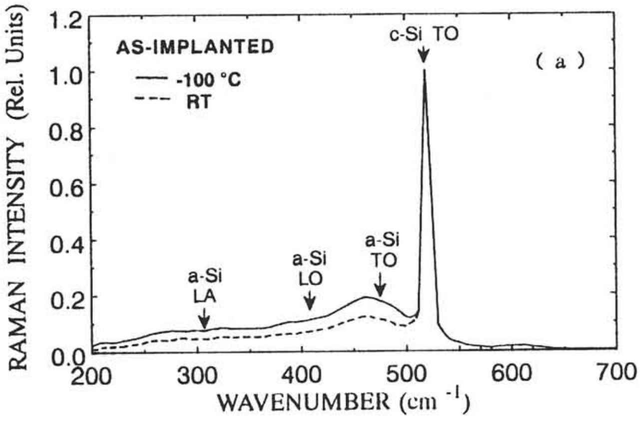


Fig. 3. Sheet resistivity versus annealing temperature for wafers implanted at RT and -100°C.

temperature sample is fully recrystallized at 600°C and the residual defect level in the -100°C sample is significantly low compared to the RT sample as shown in Fig. 2. The sheet resistivity for these specimens is consistent with the result of χ_{min}. The results of Figs. 2 and 3 indicate that the recrystallization and the impurity activation simultaneously occur at 600°C as also confirmed by the Raman spectra (Fig. 4). The Raman signal from the amorphized layer as denoted by a-Si LA, LO, TO for a specimen implanted at -100°C is larger than the one at RT, showing that the extent of the amorphization in the -100°C sample is more significant than that of RT, being consistent with the result of RBS. After 30 min annealing at 600°C, the yield arising from the amorphous layer is hardly observed and the c-Si 2TA peak becomes sharper (Fig. 4(b)). This also shows that the -100 °C sample is fully recrystallized by 600°C annealing.

The in-depth profiles of fluorine are measured for examining the interaction between remaining fluorine and residual defect as shown in Fig. 5. The fluorine content in the -100°C sample is a little higher than the RT one, implying that F atom is less mobile during the low temperature implantation. After recrystallization through 600°C annealing, the fluorine content in the -100°C sample is significantly lowered in the region deeper than 700Å which corresponds to the as-



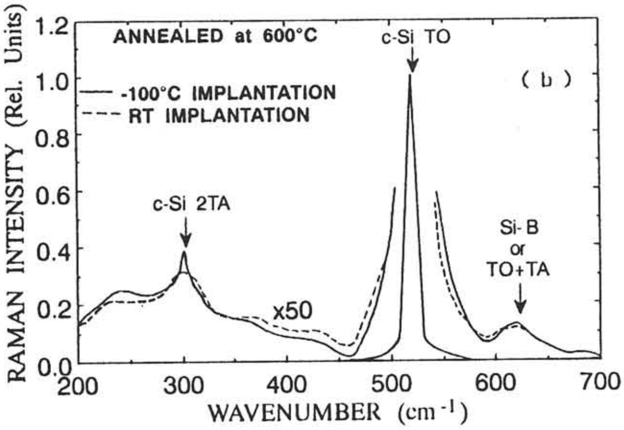
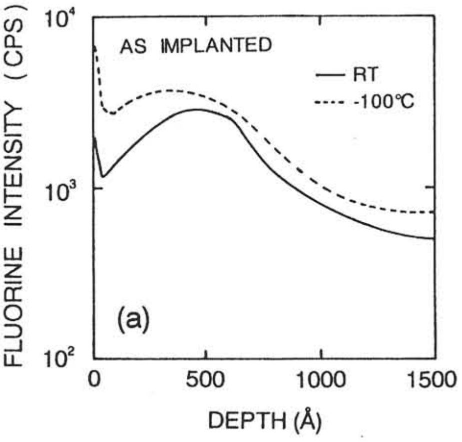


Fig. 4. Raman spectra for wafers implanted at RT and -100°C.



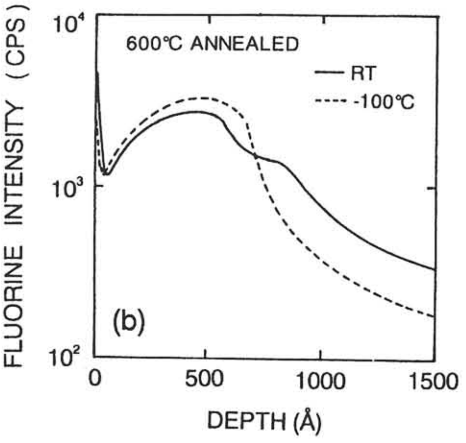


Fig. 5 In-depth profiles of fluorine in as-implanted (a) and annealed (b) samples.

implanted amorphized layer/crystalline silicon interface. Also, the fluorine profile with the RT implanted, 600°C annealed wafer exhibits a sub-peak at a depth of about 800Å. This subpeak is explained in terms that fluorine atoms precipitate in the residual defects such as microvoids and dislocations existing at a little deeper location than the initial amorphous/ crystalline interface and form stable SiF_x (x=2,3) bonds [2,4]. This subpeak is not clearly observed in the case of the low temperature implantation because of the lower density of residual defects.

For investigating the quality of the p^+n junction formed by the implantation, the leakage current was measured for specimens annealed at 600°C. It is in the range of 10^{-5} to 10^{-6}Acm^{-2} at -5V in consistence with the result reported by Brotherton et al.[5] As far as the leakage current is concerned, the advantage of the low temperature implantation is not very clear for 600°C annealing and further study is needed to clarify the influence of the implantation temperature on the leakage current.

In conclusion, the cryogenic temperature ion implantation reduces the spontaneous defect annealing during implantation. This improves the quality of the recrystallized layer as proved by RBS and Raman scattering.

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