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The production of the defects in electron-irradiated $Si_{1-x}Ge_x$ crystal evaluated by IR spectroscopy

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We present infrared (IR) spectroscopy measurements on p-type $Si_{1-x}Ge_x$ crystal ($1.5<x<5.6\%$), grown by the Czochalski method and subjected to irradiation with 2-MeV electrons. The study it focused on the effect of germanium content on the production of VO (vacancy-oxygen) defect and it's conversion to the VO_2 (vacancy-dioxygen) defect. We found that the production of the VO defect decreases with the increase of Ge content. A reduction was also observed in the conversion rate of the VO to the VO_2 defect as the Ge content increases.

The material used for the semiconductor device most is Si, because making the oxide layer can be easy. It is possible to make single crystal and high purity, also used as a substrate for the integrated circuit. Moreover, Si is abundant resource, which is overwhelmingly advantageous to the human body and environment in comparison with cadmium and arsenic of the deadly poison. The relationships between irradiation introduction defect and the Si device properties are already reported a lot. These defects understood that impurity and vacancies such as oxygen or the carbon or the other dopants and an interstitial atoms or complexes. [1] SiGe, which is chemical compound of Si and the Ge is very important materials used for the production of the high-speed device mainly. Also, SiGe is promising material for devices that have some merits as higher speed operation, lower noise level, higher operating frequencies and higher radiation tolerance.

However, it is not well known about the irradiation defects and the electrical properties of SiGe devices. Therefore, the aims of the studies are to evaluate an irradiation defect in SiGe crystals by FT-IR. Also, defects transformation by the thermal treatment.

The samples used four kinds of $Si_{1-x}Ge_x$ crystals, which included x = 0.015, 0.028, 0.040 and 0.056, respectively. The samples in this study named SiGe-1 (x = 0.015), SiGe-2 (x = 0.028), SiGe-3 (x = 0.040), and SiGe-4 (x = 0.056). And those samples were irradiated with 2 MeV electrons at RT, at a fluence of $5\times10^{17}cm^{-2}$, using the Dynamatiron accelerator at Takasaki-JAERI (Japan). After irradiation, all the samples were subjected to 20 min isochronal anneals up to 400 °C, in step of $\Delta T\approx10$ °C. And after annealing, the IR spectra were measured at RT using FT-IR spectrometer with a resolution of $1cm^{-1}$.

The initial concentrations of the oxygen and carbon impurities in the $Si_{1-x}Ge_x$ crystals are

listed in Table 1. Fig.1 shows IR spectra of sample SiGe-2 after irradiation and at 400 °C isochronal annealing. The concentration of the VO (band at 830 cm^{-1}) and the VO_2 (band at 888 cm^{-1}) defects were determined from the intensities of the corresponding peaks in the spectrum (Fig.1) and their values are also given Table 1. As can been seen from Fig.2, the production of the VO defect decreases with increases Ge content. This could be explained by the fact that at high concentrations, Ge atoms reduce the annihilation rate of the primary defects during irradiation. Ge atoms act as trapping sites for primary defects, which annihilate on them. As a result, the available vacancies for the formation of the VO defects are reduced. Besides some of the VO centers are trapped near Ge atoms. It is expected that these VO centers, perturbed by neighboring Ge atoms to exhibit a higher migration barrier for diffusion and therefore their conversion to the VO_2 defects to be more difficult.

Table I The initial oxygen and carbon concentrations as well as the concentration of the VO defect and it's conversion to the VO_2 defect of the $Si_{1-x}Ge_x$ samples used.

Sample	x%	$[O_i]_o$ 10^{17} cm^{-3}	$[C_s]_o$ 10^{16} cm^{-3}	[VO] 10^{16} cm^{-3}	$[VO_2]/[VO]$
SiGe-1	1,5	11.5	<1	2.7	0.32
SiGe-2	2,8	9.8	3.8	2.3	0.18
SiGe-3	4,0	4.9	4.5	2.0	0.02
SiGe-4	5,6	6.9	4.9	2.1	0.03

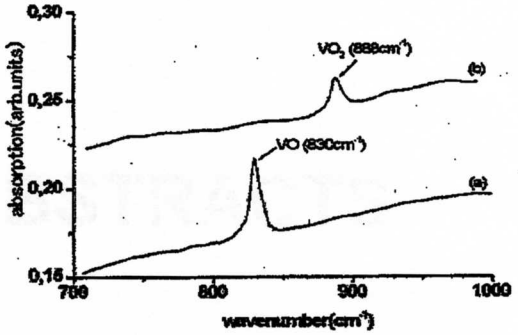

Fig.1. Fragments of the IR spectra of the SiGe-2 sample (a) after irradiation and (b) at 400°C.

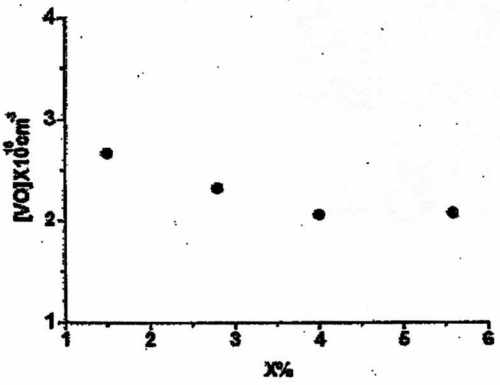

Fig.2 VO concentration versus Ge content of the $Si_{1-x}Ge_x$ samples used

Reference

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[2] C. A.Londos, A. Andrianakis, D. Aliprantis, H. Ohyama, V. V. Emtsev, G. A. Oganesyan, Physica B 401-402, 487 (2007).