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Proton irradiation effects on the properties of silicon wafer

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1. Introduction

The study the effect of energetic particle irradiation on the properties of semiconductor devices has been interested for developing and utilizing semiconductor irradiation detectors under various irradiation conditions such as large hadron collider in CERN. Despite of the interest and various researches, the effects of irradiation defects in silicon have not been fully determined.

In this study, we investigated the influence of proton irradiation on carrier lifetime and electrical resistance of silicon wafers. Proton is known to make a stable irradiation defects in silicon [1]. These irradiation defects form a new energy level within the band gap, hence affect the properties of silicon [2-5].

2. Experimental

2.1 Preparation of proton irradiation specimens

Silicon substrates were prepared by dicing the wafer as shown in Fig. 1. The size of the substrate was 10 mm × 10 mm. Proton irradiation was performed by MC-50 cyclotron in Korea Institute of Radiological Medical Sciences (KIRAMS). The energy of proton was fixed to 10 MeV, and the fluence was changed from 10^{10} to 10^{13} cm^{-2}. Fluence levels for each specimen designation are shown in Table 1.

Fig. 1 Diced silicon wafer

Table I: Specimen data

Specimen	A	B	C	D
Fluence (cm^{-2})	0	10^{10}	5×10^{10}	10^{11}
Specimen	E	F	G	H
Fluence (cm^{-2})	5×10^{11}	10^{12}	5×10^{12}	10^{13}

2.2 Carrier lifetime of proton-irradiated substrates

First, we measured carrier lifetime of proton irradiated silicon substrates. For measuring carrier lifetime, we used micro-wave PCD (photoconductivity decay) equipment (WT-2000, Semilab) at KICET (Icheon Gyeonggi-do). The equipment is shown in Fig. 2.

Fig. 2 Micro-wave PCD lifetime scanner equipment (WT-2000, Semilab)

The schematic of micro-wave PCD technique is shown in Fig. 3. Electron-hole pairs are generated by laser source. Generated electron-hole pairs then change the microwave reflectivity of specimen. The equipment measures this microwave reflectivity variation to measure carrier lifetime.

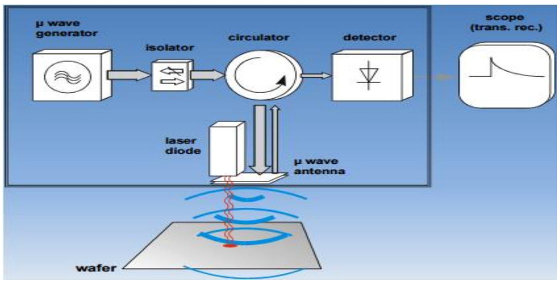

Fig. 3 Schematic of Micro-wave PCD

2.3 Sheet resistacne of silicon

Electrical resistance of proton-irradiated silicon substrates was evaluated using four probe method [6, 7]. We used CMT- SR 1000N (AIT) at Myongji University. The probe system is shown in Fig. 4.

3. Results

3.1 Carrier lifetime

Fig. 5 shows the mapped carrier lifetimes of proton-irradiated substrates, which were placed side by side. Specimen 'B' with the irradiation dose of 10^{10} cm^{-2} was located first, and then the specimens were placed at right-hand side as increasing order of dose levels. As is shown, the carrier lifetime is decreased from left to right, i.e., as increasing irradiation dose level. .

Fig.4 Four probe resistivity measurement system (AIT, CMR-SR 1000N)

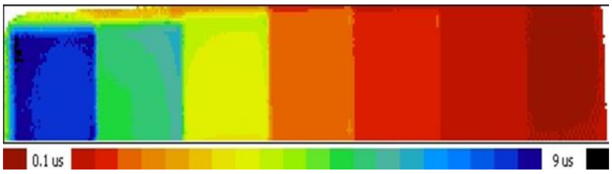

Fig. 5. The mapping of carrier lifetime of proton-irradiated silicon substrates (left: 10^{10} cm^{-2}, right:10^{13} cm^{-2})

Fig. 6 shows the variation in carrier lifetime as a function of irradiation dose. The carrier lifetime of pre-irradiation silicon was around 11 μs, and decreased as the irradiation dose increases. At dose-level greater than 10^{12} cm^{-2}, the carrier lifetime was as small as around 0.1 μs.

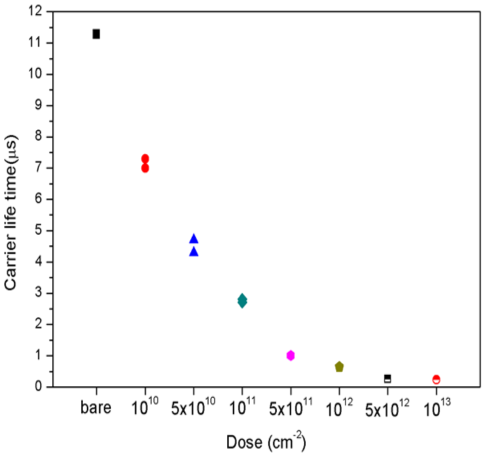

Fig.6. Carrier lifetime as a function of irradiation dose

3.2 Electrical resistance

Fig. 7 shows the measured sheet electrical resistance of the proton-irradiated substrates. The sheet resistance was kept almost constant up to irradiation dose of 10^{12} cm^{-2}, and then rapidly increased as the irradiation dose increases larger than 10^{12} cm^{-2}.

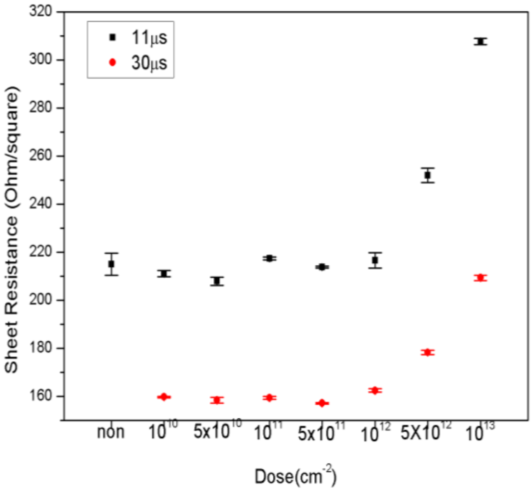

Fig.7. Sheet resistance-dose curve

4. Summary

The irradiation defects generated by proton irradiation affect the carrier lifetime by capturing excess carriers and the electrical resistance by hindering the carrier movement. In this study, the carrier lifetime of proton-irradiated silicon substrates was found to decrease rapidly as the irradiation dose increases. On the other hand, the sheet electrical resistance was not significantly changed up to the irradiation dose level of 10^{12} cm^{-2}. Hence, proton irradiation less than dose level of 10^{12} cm^{-2} can be utilized to decrease carrier lifetime significantly without sacrificing the electrical resistance.

REFERENCES

[1] P Hazdra , K Brand, J Rubeš, J Vobecký, Microelectronics Journal Volume 32, Issues 5– 6, (2001)

[2] P. Lévêquea, , , P. Pellegrinoa Halléna, G. Svenssona, V. Priviterac, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms Volume 174, Issue 3, April (2001), Pages 297– 303

[3] M. Jelinek, J. G. Laven, M. Rommel, W. Schustereder, H.-J. Schulze L. Frey, and R. Jobe, ECS Transactions, 64 (11), (2014)

[4] P. Hazdra, K. Brand, J. Vobecký, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms Volume 192, Issue 3, (2002)

[5] D.C. Schmidt, J.F. Barbot, C. Blanchard, E. Ntsoenzok, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Volume 132, Issue 3, (1997)

[6] F. M Smits, Measurement of sheet resistivityes with the four-point probe, (1957)

[7] LB valdes, Resistivity measurements on germanium for transistors, IRE, (1964)