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Development of high radiation tolerance detector with CIGS

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In the hadron collider experiments, many silicon detectors have been used for the tracking detection. When these semiconductor detectors are exposed to high radiation level, their detector performances are degraded by the radiation damage. It becomes a serious problem for the future collier experiment expected higher radiation levels. Therefore, new semiconductors in place of silicon with high radiation tolerance have been widely developing in the world.

A $\mathrm{Cu(In_{1-x}, Ga_x)Se_2}$ (CIGS), which is an alloy semiconductor of $\mathrm{CuInSe_2}$ and $\mathrm{CuGaSe_2}$, is one of the candidates for radiation hard detector. It has been confirmed that CIGS solar cells can recover from radiation damage through thermal annealing, and CIGS is expected to become a new detector with high radiation tolerance for using in future hadron colliders ($O(10^{17})\ \mathrm{n_eq/cm^2}$). We developed the prototype of CIGS detectors with 2 μm thickness which composed of a pn (CIGS-CdS) junction, investigating radiation tolerance of them with two irradiation experiments.

In the first experiment at Heavy Ion Medical Accelerator in Chiba (HIMAC), the heavy ion ($^{132}\mathrm{Xe}^{54+}$) beam with the energy of 400 $\mathrm{MeV/u}$ was irradiated to the CIGS detectors, and amount of collected charge from $^{132}\mathrm{Xe}^{54+}$ signals and the leakage current were measured during the $^{132}\mathrm{Xe}^{54+}$ irradiation.

The collected charge after exposure to a radiation dose of 0.6 MGy was degraded to a half of before irradiation, but recovered to 97$\%$ of the pre-irradiation level after 2-hours thermal annealing at 130 $^\circ$C. We also confirmed second recovery of collected charge to 94$\%$ by 50-minutes thermal annealing at 130 $^\circ$C after more irradiation with radiation dose of 0.2 MGy. We observed the continuously recovery from radiation damage and found the possibility of long-term operation in high radiation environments with periodic thermal treatments.

In the second experiment at Cyclotron and Radioisotope Center (CYRIC), the fluence with $7.5 \times 10^{15}\ \mathrm{n_{eq}/cm^2}$ by 70 MeV/c proton beam irradiated to CIGS solar cells. We investigated recovery mechanism in the CIGS. In this study, we treated the samples by thermal annealing after proton irradiation samples under various temperature conditions, investigating temperature dependence of recovery rates and a behavior of defect levels using Deep Level Transient Spectroscopy (DLTS) measurement.

I will introduce the progress of CIGS detector development and the recovery mechanism from radiation damage with two irradiation experimental results.

Auteur principal: ITABASHI, Kosuke (High Energy Accelerator Research Organization)

Co-auteurs: Dr NISHINAGA, Jiro (National Institute of Advanced Industrial Science and Technology); TOGAWA, Manabu (High Energy Accelerator Research Organization); Dr MASAYA, Miyahara (High Energy Accelerator Research Organization); Dr HIRONORI, Okumura (University of Tsukuba Faculty of Pure and Applied Sceinces); Dr ISOBE, Tadaaki (Physical and Chemical Research)

Orateur: ITABASHI, Kosuke (High Energy Accelerator Research Organization)

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