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Study of radiation tolerance of Cu(In,Ga)Se2 detectors

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The European Organization for Nuclear Research (CERN) is planing a major update of the accelerator to HL-LHC and future hadron collider. These major upgrades give higher radiation doses to detectors, and degradation of semiconductor properties will be more serious problem. $\mathrm{Cu(In_x, Ga_{1-x})Se_2}$ (CIGS) is attracting attention a new semiconductor material that can be used for long-term operation in high-radiation environments.
A CIGS which is an alloy semiconductors of $\mathrm{CuInSe_2}$ and $\mathrm{CuGaSe_2}$, has been widely developed as a solar cell. It is known to have a recovery mechanism for radiation damage by a thermal annealing, and we have been developing a particle detector using the CIGS with high radiation tolerance. The purpose of this study is to clarify the recovery mechanism of the radiation damage in the CIGS through irradiation experiments at Heavy Ion Medical Accelerator in Chiba (HIMAC) and Cyclotron and Radioisotope Center (CYRIC).
In the HIMAC experiment, we irradiated heavy ion beams ($^{132}\mathrm{Xe}^{54+}$) with the energy of 400 $\mathrm{MeV/u}$ to the CIGS detector with 2 $\mu\mathrm{m}$ thickness, and the amount of collected charge from $^{132}\mathrm{Xe}^{54+}$ signals and the leakage current were measured during the beam irradiation. After irradiation of 0.6 MGy, the amount of collected charge from xenon signals was decreased to 50% before irradiation. Afterwards, as a result of the thermal annealing for two hours at 130°C, the amount of collected charge was recovered to 97% before irradiation. Moreover, after $^{132}\mathrm{Xe}^{54+}$ beam irradiation again, we observed a second recovery of collected charge from 80% to 94% by the thermal annealing for another 50 minutes at 130°C. It indicates the possibility of the long-term operation in high radiation environments with periodic thermal treatments.
In the CYRIC experiment, proton beams with dose of 7×10^{15} $\mathrm{MeV \cdot n_{eq}/cm^2}$ irradiated to the CIGS solar cells with 2 $\mu\mathrm{m}$ thickness, and investigated to trend of thermal time and temperature in the recovery of semiconductor properties.

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