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[P02] Development of a method for calculating displacement damage dose of semiconductors by space radiation using PHITS code

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In the space environment, semiconductors used in many devices are irradiated with particles such as protons, neutrons, electrons, and heavy ions. The atomic displacement caused by these particles degrades the electrical performance of the devices. The atomic displacement of a semiconductor is proportional to the Displacement Damage Dose (DDD), which is expressed as the integral of the non-ionizing energy loss (NIEL) and the particle fluence. In order to simulate DDD of semiconductors in space, we have developed a method for calculating DDD in the Monte Carlo Particle and Heavy Ion Transport code System (PHITS), using the same calculation method as that for the number of Displacements Per Atom (DPA) of metals over a wide energy range [Y. Iwamoto et al. J. Nucl. Mater. 538, 152261 (2020)]. This method includes the calculation of the Coulomb scattering cross section between charged particles and a target, the calculation of nuclear reactions, and the calculation of charged particle productions under neutron irradiation. For proton, neutron and electron irradiation of silicon, PHITS results are consistent with numerical data obtained by the Screened Relativistic (SR) Nuclear and Electronic Stopping Power Calculator for semiconductors. The defect production efficiencies obtained from the recent molecular dynamic simulations for SiC, InAs, GaAs, and GaN semiconductors [F. Gao et al. Phys. Rev. Mater. 5, 033603 (2021)] were also implemented in PHITS. Results show that, among these semiconductors, GaAs is the most sensitive to displacement damage and SiC is the most resistant to damage when irradiated with 10 MeV protons. This work was supported by JSPS KAKENHI Grant Number JP19H02652.

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