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Effect of proton fluence on radiation defect structure of high-purity silicon for particle detectors

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High-resolution photoinduced transient spectroscopy (HRPITS), infrared absorption (FTIR) and photoluminescence (PL) measurements have been applied to determining the properties and concentrations of radiation defect centers formed in high-purity FZ silicon due to the irradiation with 23-MeV protons. The selected four proton fluences were equivalent to 1E14, 5E14, 1E15, and 5E15 cm^-2 of 1-MeV neutrons. Before the proton irradiation, the material resistivity had been of ~ 2000 Ωcm. The irradiation with each fluence resulted in obtaining the material with semi-insulating properties, indicated by the resistivity above 2×10^5 Ωcm. The HRPITS results revealed that the increase in the resistivity is due to the formation of shallow, deep, and midgap radiation defect centers that are likely to be responsible for the charge compensation in the irradiated material. The FTIR results revealed the presence of both VO and V2O centers, as well as of the divacancies in V2 (0) and V2 (-) charge states. In the low-temperature PL spectra, a number of lines attributed to the excitons bound to the defect centers were observed. The C, G, and T lines are related to the complexes involving carbon atoms and the W line is probably related to Si interstitials. The dependences of the radiation defect centers concentrations as a function of the proton fluence were determined.

Author: Prof. KAMINSKI, Pawel (Institute of Electronic Materials Technology, 133 Wolczynska St., 01-919 Warszawa, Poland)

Co-authors: Dr DIERLAMM, Alexander (Karlsruhe Institute of Technology, Hermann-von-Helmholtz Platz 1, 76-344 Eggenstein-Leopoldshafen, Germany); Mrs SURMA, Barbara (Institute of Electronic Materials Technology, 133 Wolczynska St., 01-919 Warszawa, Poland); Prof. KRUPKA, Jerzy (Institute of Microelectronics and Optoelectronics, Warsaw University of Technology, 75 Koszykowa St., 00-662 Warszawa, Poland); Mr KWESTARZ, Michal (Topsil Semiconductor Materials SA, 133 Wolczynska St., 01-919 Warszawa, Poland); Dr KOZLOWSKI, Roman (Institute of Electronic Materials Technology, 133 Wolczynska St., 01-919 Warszawa, Poland)

Presenter: Prof. KAMINSKI, Pawel (Institute of Electronic Materials Technology, 133 Wolczynska St., 01-919 Warszawa, Poland)

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