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Characterization of X-ray Energy Responses of both n-type and p-type Silicon Tomography Detectors Irradiated with Fusion Produced Neutrons

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Two- or three-dimensional X-ray tomographically reconstructed data analyses by the use of multichannel silicon semiconductor detectors play an important role in investigating plasma electron behaviour in controlled thermonuclear fusion research. However, recent harsh radiation environments in fusion experiments with deuterium-tritium (D-T) and/or deuterium-deuterium (D-D) reactions pose the serious problem of radiation-induced degradation in X-ray detection characteristics of silicon semiconductor detectors.

In order to clarify the effects of fusion-produced neutrons on silicon semiconductor x-ray detectors, the characterization experiments for both n-type and p-type multichannel silicon x-ray-tomography detectors used in the Joint European Torus (JET) and the GAMMA 10 tandem-mirror are carried out by utilizing D-T fusion neutron production at the Fusion Neutronics Source (FNS) facility of Japan Atomic Energy Research Institute (JAERI). These detectors are characterized before and after the fusion-produced neutron exposure by the use of synchrotron radiation from a 2.5-GeV positron storage ring at the Photon Factory of High Energy Accelerator Research Organization (KEK). Different fluence dependence is found between these two types of detectors; (i) for the n-type detector, the recovery of the degraded response is found after the neutron exposure beyond around 1013 neutrons/cm2 onto the detector. A further finding is followed as a “re-degradation”by a neutron irradiation level over about 1014 neutrons/cm2. On the other hand, (ii) the energy response of the p-type detector shows only a gradual decrease with increasing neutron fluences. Similar characterization experiments for p-type detectors with different effective doping concentrations are also carried out. These properties are interpreted by our proposed theory on semiconductor x-ray responses in terms of the effects of neutrons on the effective doping concentration and the diffusion length of a semiconductor detector.

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