Recovery of x-ray energy responses of neutron irradiated semiconductors

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Introduction

One of the most critical issues in the use of semiconductor detectors under the circumstances with nuclear fusion produced neutrons is to find a method for recovering the degraded semiconductor response without vacuum break (in situ recovering), or to find out a relation between the degradation effects and neutron fluence into semiconductors. From this viewpoint, we investigate a rather simple and externally controllable method of supplying detector bias to a damaged detector.

Experimental Apparatus

X rays monochromatized with a double-crystal [Si(111)] monochromator (BL-15C) in the energy range of 6 to 20 keV are incident on a semiconductor detector array irradiated with the neutron fluence of 1×10^{13} neutrons cm^{-2} in the Joint European Torus (JET) tokamak. Here, neutrons are produced by deuterium-deuterium (D-D) plasma fusion experiments in JET (2.5 MeV neutrons). The detector array consists of 35 channels with anodes 4.5 mm by 0.96 mm at 0.99 mm spacing with common cathodes. The detector is fabricated using a 300-μm-thick n-type-silicon wafer.

Experimental Results

Figure 1 shows data on the x-ray energy responses of the neutron damaged JET detector array at the applied bias of 1.5 (the filled circles), 3.0 (the open circles), 6.0 (the triangles), and 10.0 V (the squares). Here, we extend to apply our proposed theoretical formula [1-3] under neutron circumstances: The essential terms in the formula are the parameters of d_{dep}, L, and d_{waf}, where d_{dep}, L, and d_{waf} denote the depletion layer thickness, the minority-carrier diffusion length, and the wafer thickness, respectively. The value of d_{waf} is unchanged. Therefore, we need information on the remaining two terms of d_{dep} and L to fit the data in Fig. 1 using the formula. The term of d_{dep} may be effected due to neutron irradiation. In the present report, we directly measure the values of d_{dep} after neutron irradiation by means of an impedance (C-V) analyser. On the other hand, the term of L is tried to be estimated from the data fitting to the x-ray energy response in Fig. 1 under the assumption of the validity of the formula [1-3] even for such a damaged detector. The solid, dashed, dotted, and dot-dashed curves in Fig. 1 stand for fitting curves to the above four biasing data sets using the values of observed d_{dep} along with the same value of L=20±5 μm for all traces.

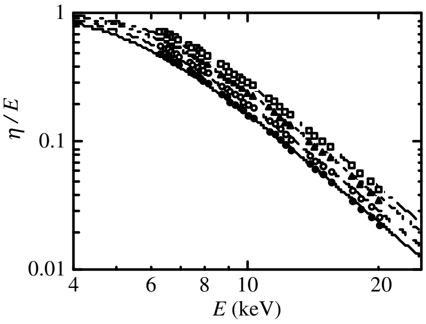

Fig. 1 The x-ray response data obtained from the D-D neutron damaged detector at the applied bias of 1.5, 3.0, 6.0 and 10.0 V are plotted by the filled circles, open circles, triangles, and squares, respectively. The data are well fitted by the theoretical curves (see Refs. [1,2]) using the values of observed d_{dep} at each applied bias along with the same value of L=20±5 μm.

The evidence of (i) the availability of the use of the same value L for tracing all data, and (ii) the existence of the degradation as compared with the case of L=50 μm obtained before neutron irradiation implies the availability of the formula even for such damaged detectors. The decrease in L is expected to be interpreted by the formation of trapping centres due to lattice damages for intercepting x-ray created diffusion charges in the field-free substrate region. According to the above mentioned physics interpretations, these damaged energy responses including the applied bias dependence will be calculated when we obtain more detailed dependence formulae for d_{dep} and L as a function of neutron fluence.

References

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