Radiation hardness tests of silicon strip detectors at the cyclotron-based neutron irradiation station of the V G. Khlopin Radium Institute

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Five double-sided silicon strip detectors manufactured by CiS, Germany, were irradiated at the MGC-20 cyclotron-based neutron irradiation station of KRI, St.-Petersburg, and tested at SINP MSU, Moscow, Russia. The detectors were irradiated with mono-energetic neutrons generated in the deuterium gas target in the D(d,n) reaction. The energy of the deuterium beam was determined by irradiating nickel foils with a thickness of 100 μm and using interpolated data on the yield of the ^{nat}Ni(d,X)^{61}Cu reaction. The neutron spectrum calculated from the measured deuteron energy was then used (with the data on reactions' cross sections) to determine the neutron fluxes and reduce them to the 1 MeV equivalent neutrons. The neutron fluxes were monitored by irradiating aluminium foils and measuring the activity of ^{27}Mg and ^{24}Na from the ^{27}Al(n,p)^{27}Mg and ^{27}Al(n,a)^{24}Na reactions. The samples were exposed to the neutron fluences (reduced to 1 MeV) of 2.06×10^{12}, 3.03×10^{12}, 3.93×10^{12}, 11.2×10^{12}, and 2.6×10^{13} n/cm^2. Prior to and after irradiation, the following detector parameters were determined at SINP MSU: total leakage current ($I_{\rm bias}$), resistance of the FOXFET biasing resistors at the working biasing voltage ($R_{\rm FOXNET}$), inter-strip resistance between adjacent strips at the working bias ($R_{\rm interstr}$), depletion voltage of the p-n junctions of strips ($V_{\rm op}$), leakage currents of p- and n-strips at depletion voltage or exceeding it by 10 V ($I_{\rm str}$), and the leakage currents of the AC capacitors at depletion voltage or exceeding it by 10 V ($I_{\rm AC}$).

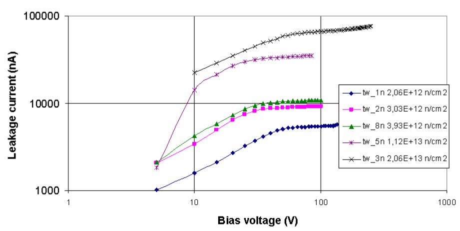

Figure 1: Total leakage current (n side, normalised to 20°C) as a function of bias voltage for different neutron fluences

The total leakage current of all strips of the irradiated samples as a function of bias voltage is shown in Fig. 1. The flat parts of the I(V) curves give an indication of the bulk volume thermal generation current as the main component of the total leakage current. Some typical inter-strip resistance - bias voltage relationships for separate strips of all irradiated samples which were used to determine the galvanic separation voltage are shown in Fig. 2-top. After irradiation, the voltage drop across the bias (FOXFET) resistors significantly increases, which results from the rapid increase of the leakage current coupled with the slow resistance increase of the resistors. This means that for detectors with the FOXFET resistors used in harsh radiation environment, the working voltage depends not only on the full depletion voltage but even more on the leakage current. The full depletion voltage V$_{fd}$ as a function of neutron fluence is shown in Fig. 2-bottom. In the same figure, values obtained in 2009 from the capacitance - voltage relationship for CiS sample pad test structures are shown. The 10^{13}n/cm^2 fluence is interpreted as a conductivity type inversion point. We observe a similar dependence of full depletion voltage on neutron fluence for double-sided microstrip sensors and for sample pad structures produced by the same manufacturer and measured using different procedures.

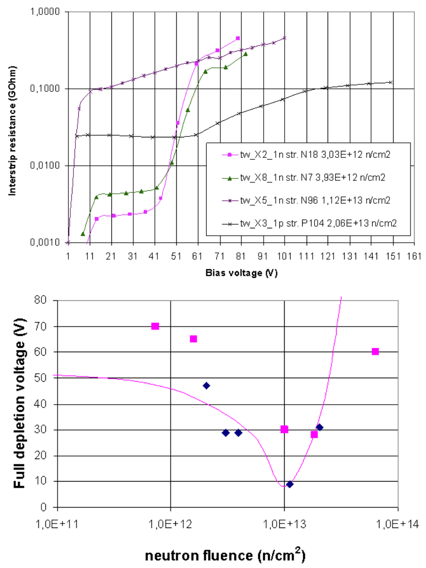

Figure 2: (top) Resistance between adjacent strips as a function of bias voltage; (bottom) full depletion voltage as a function of neutron fluence. The squares denote the strip detectors, the diamonds the CiS test structures.

The procedures developed for irradiation and measuring parameters of double-sided detectors provide results conforming to the expected values and to the results obtained using other procedures. This makes it possible to use the developed procedures in further radiation tests of such detectors.