The Upgrade of the Ion and Neutron Irradiation System to Investigate the Soft Error of Integrated Circuit Systems

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A high-intensity fast neutron beam facility in CYRIC has been developed at the straight beam line (32 course) from the K = 110 MeV AVF cyclotron since 2004. This course is used for the cross section measurement of the nuclear physics, testing of semiconductors for single-event effects, and dosimetry development (Fig. 1). The AVF cyclotron can provide the proton beam with an energy range from 14 to 80 MeV at present. Figure 1 shows the schematic view of the neutron source. The quasi-monoenergetic neutron beam is produced by using the ^{7}Li(p,n)^{7}Be reaction. The primary proton beam is bombarded to the water-cooled production (Li) target. After penetrating the target, the proton beam is bent in the clearing magnet by 25° and stopped in the water-cooled beam dump which consists of a carbon block shielded by copper and iron blocks. The typical neutron beam intensity is about 10^{10} n/sr/sec/uA with a beam spread of about 5% for the beam energy and ± 2° for the horizontal and vertical directions. The neutron beam is collimated by iron blocks of 595 mm thick and sufficiently low background at the off-axis position. The available flux of the neutron beam is about 10^{6} n/cm^{2}/sec/uA at the sample position which is located at about 1.2 m downstream of the production target. The thermal neutron flux at the sample position is about 2×10^{4} n/cm^{2}/s, which was measured by a foil activation method combined with imaging plate.

The samples which are irradiated by the neutron to study the radiation damage of the integrated circuit system and many kinds of memory and CPU devices are set in front of the flange to extract the neuron beam. The integrated circuit system has many components which have each functions such as the SRAM, DRAM, FPGA, and many other functioned ICs, and we need to irradiate the neutron beam to each component to check which device has effect again the radiation, and we can know the radiation damage mechanism in more detail by studying the position dependence of the soft error or radiation damage. Then, to realize the efficient experiment for the radiation damage, we developed the remote movable table to control the sample position by the support from Ministry of Economy, Trade and Industry. We can control the irradiation positions remotely and can monitor the soft error rate with any combination of the experimental parameters such as the beam position, beam intensity etc. The installation is ready now, and will be operated from next year.

Figure 2 shows a typical energy spectrum of the neutron beam at 65 MeV which was produced by 70 MeV protons. The thickness of the Li target was 9.1 mm. The energy spectrum was measured by the time of flight (TOF) method at 7.37 m downstream of the Li target. The energy spread of the neutron beam was 4 MeV which was included the time spread of the primary beam of 1.6 ns, the energy loss difference due to the thick Li target, and so on. The ratio of peak area to the total fast-neutron flux is about 0.4. The detection system of the fast neutron consists of a liquid scintillator of NE213 type with the size of 140 mm (diameter) × 100 mm (thickness), a 5 inch photomultiplier tube, HAMAMATSU H6527, which were assembled by OHYO-KOKEN cooperation, and a CAMAC data acquisition (DAQ) system. The irradiation room is a narrow room which size is 1.8 m (W) × 10 m (L) × 5 m (H). The irradiation sample can be placed at 1.2 m downstream of the Li target, as shown in Fig. 1. The spot size of the neutron beam is about 84 mm (horizontal) ×84 mm (vertical) at that point. The flux of the neutron beam can be varied from about a few hundreds n/sec to 3×10^{10} n/sr/sec. The largest amount of the accumulated flux in one experiment was about 5×10^{11} n/cm^2 for the practical irradiation time of 50 hours. The flux of the neutron beam is monitored by a primary beam current in the beam dump and a NE102A plastic scintillator with the size of 100 mm (diameter) × 1 mm (thickness) during the irradiation experiment. This facility has been listed as one of the high intensity fast neutron field facility with quasi-monoenergetic beam at EURADOS[1)].

Reference

1) EURADOS (European Radiation Dosimetry) Report 2013-02 “High-energy quasi-monoenergetic neutron fields”

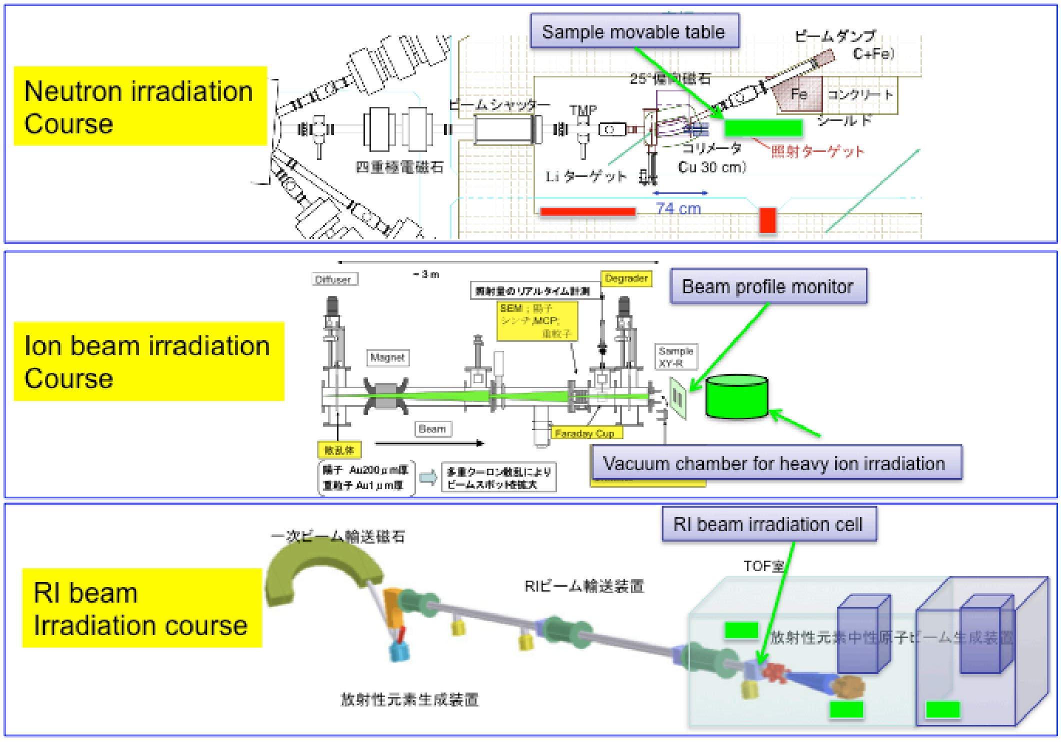

Figure 1. Overview of the setups of irradiation system of neutron (up) at 32 course, ion (middle) at 33 course, and RI beam (down) at 51 course.

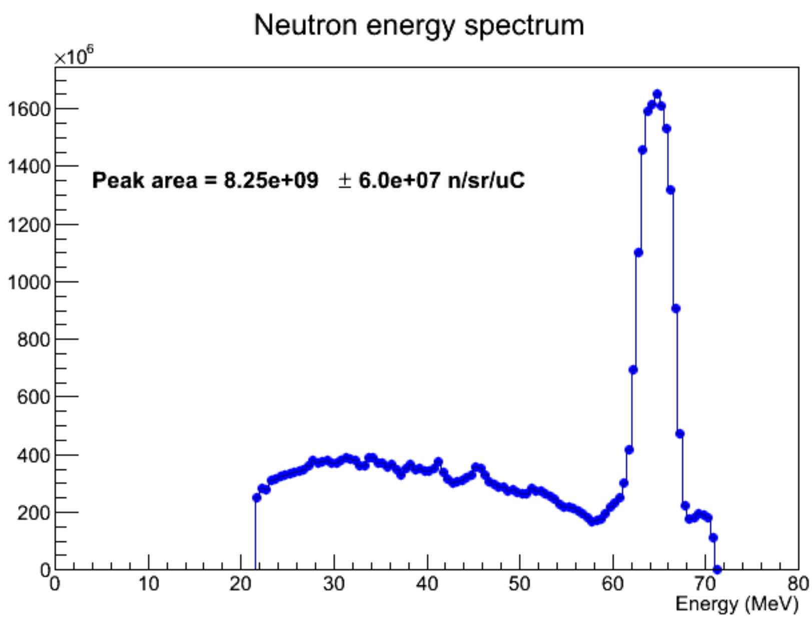

Figure 2. A typical energy spectrum of the neutron beam at 65 MeV. The neutron flux of a peak area from 58 to 68 MeV is 8.25×10^9 neutrons/sr/μC. The ratio of the peak area to the total fast neutrons is about 0.4. The tail at around 70 MeV is attributed to the flame overlap due to the cyclotron RF cycle.