CO8-1 # Research and Development of Diamond dose Rate Detector for Radiation Mapping System in Highly Active Environments

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INTRODUCTION: Measurements of radiation dose rates in highly active environments, such as the Fukushima Daiichi Nuclear Power Plant or Sellafield in UK, is challenging due to the extreme environments encountered and restricted access. Therefore, novel radiation detector technology is required to address these challenges. One such example of a radiation detection material is diamond, as it is able to withstand and measure high radiation intensities, is chemically inert and formable into extremely small, sensitive detectors. These detectors generate small currents when exposed to radiation, and if the radiation levels are high enough this can be measured. Testing of such detectors is not possible in routine laboratories due to the requirement to have high active radiation sources in UK. However, through a new collaboration formed through Kyoto University-the University of Bristol bilateral symposia, UK researchers are accessible to the high active radiation source at Kyoto University Research Reactor Institute (KURRI). This report presents some preliminary results from radiation testing of diamond detectors developed by University of Bristol at Co-60 facility in KURRI.

EXPERIMENTS: Three diamond detectors as shown in Fig. 1 (S1, C1 and C2) were exposed to varying dose rates using a Co-60 irradiator irradiation facility at KURRI. This facility has a strong Co-60 source in a large irradiation room that allows exposure to a large range of dose rates from approximately 0.1 Gray/hour up to >4000 Gray/hour by the change of the irradiation position. The diamond detectors were located on the end of a 50 meter cable and controlled using custom built software that applies a 300 V bias voltage and records current data every 50 ms. For each dose rate a background was recorded for 30 seconds before and after the source was introduced, with 60 seconds of data collected while the diamond was exposed to the source. The mean and standard deviation of the current recorded was calculated for each dose rate and background measurement. A background subtraction, between the start background and measurement current, was performed to allow the current generated by irradiation to be plotted.

RESULTS: The response of the S1 detector to various dose rates from Co-60 are shown in Fig. 2 as an example, where the data point is a mean of 60 seconds of data and the error bars are one standard deviation to give an indication of detector stability. Detector S1 shows a stable and linear response, with an increasing dose rate being proportional to an increase in current measured. This response would allow the use of this detector in civil nuclear applications as a reliable calibration factor can be derived. Following testing using the Co-60 facility, any detectors that show promise for use, such as S1, will be tested further using the other facilities present at KURRI. This will include exposure to different energy gamma radiation such as Cs-137, to establish if the incident gamma energy has any effect on detector response. Additionally, upon restart of the Kyoto University Research Reactor (KUR) and Kyoto University Critical Assembly (KUCA) the detector response in highly active gamma and neutron/gamma mixed fields can be investigated.

Fig. 1 Diamond detector (left: S1, right: C1,C2)

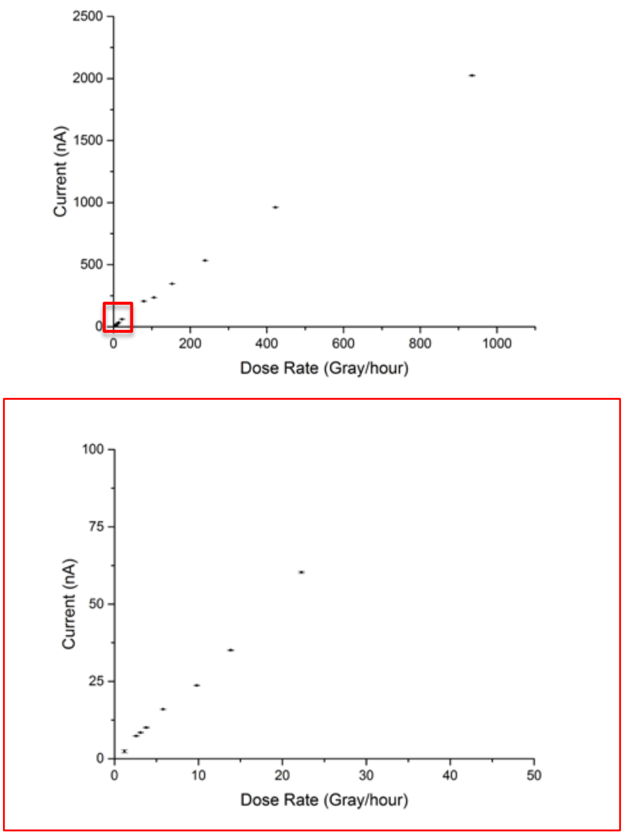

Fig. 2 Dose rate response of S1 detector

CO8-2 **Development of Non-destructive Methods Adapted for Integrity Test of Next Generation Nuclear Fuels**

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INTRODUCTION: A fast reactor system with trans-uranium fuels containing minor-actinide is expected to be effective for the incineration of high-level radioactive wastes. In order to realize the fast reactor system, integrity evaluation of the fuels with high activity is required for the safety operation. However, present techniques are considered to be difficult to apply the evaluation of the fuels with high radioactivity and high decay heat. In order to develop the related methodology adapted for the integrity evaluation, the N-DeMAIN (Development of Non-Destructive Methods Adapted for Integrity test of Next generation nuclear fuels) project has been started from October 2014. In the project, the neutron resonance transmission analysis is adapted for the identification and quantification of nuclides in the fuels by time-of-flight (TOF) measurement. In addition, the determination of temperature distribution in the fuels based on Doppler-effect and neutron imaging are conducted by the neutron resonance technique. To obtain accurate data by these methods, high quality neutron beam regarding neutron flux, time resolution and spatial resolution is required. The 46 MeV electron accelerator in Kyoto University Research Reactor Institute (KURRI-LINAC) will be used for the project because KURRI-LINAC is the only pulsed neutron facility where nuclear materials can be utilized in Japan. In order to satisfy the neutron beam quality required to successfully execute the experiments described above, the design of the neutron source, especially the moderator, reflector and collimator, should be improved and optimized. In this project, the neutron source system including moderator and reflector was newly developed as shown in Fig. 1 and the collimator in 12 m beam line was also re-arranged. The characteristic of the system was investigated experimentally.

Fig. 1 Newly developed neutron source system

EXPERIMENTS: A water-cooled photo-neutron target was set at the center of the neutron source system located in the target room. To enhance the neutron flux in thermal and epi-thermal regions, the size of the moderator of polyethylene was 5 cm thickness and 15 cm square. The measuring station at 12 m from the target on the 135 degree beam line was selected in this project. A lead shadow bar, 5 cm in diameter and 20 cm long, was placed on the neutron beam axis in front of the neutron source system to reduce intense gamma-flash from the target effectively. The collimators of polyethylene with 10% boron of 20 cm thickness were set at following positions; 15, 10, 5 cm in inner diameter at 3, 9, 12 m from the target, respectively. Neutron spectrum measurements were obtained from capture reaction rate of ^{10}B (22 mm diameter, purity 96.98%) and dummy samples. A BGO scintillator (2 inch diameter and 2 inch long) was used for measuring total energy absorption gamma-rays. The conditions of the accelerator were as follows: average beam current was 14.5 μA, frequency was 50 Hz and pulse width was 100 ns.

RESULTS: Measured neutron spectrum is shown in Fig. 2. The neutrons in a few keV energy regions could be measured owing to the reduction of gamma-flash influence. The thermal neutron flux of 2.36×10^2 [n/cm^2/μA/s] and the epi-thermal neutron flux of 5.72×10^2 [n/cm^2/μA/s] were obtained under this experimental condition. It was found we can obtain the maximum thermal neutron flux of 4.72×10^4 [n/cm^2/s] and the maximum epi-thermal neutron flux of 1.14×10^5 [n/cm^2/s] under 6 kW operation of KURRI-LINAC.

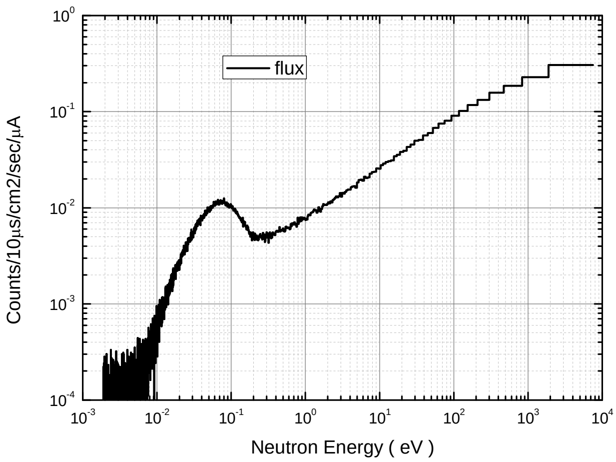

Fig. 2 Measured neutron spectrum

Present study includes the result of “Development of Non-Destructive Methods Adapted for Integrity test of Next generation nuclear fuels” entrusted to the Kyoto University by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).