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Variation of Transmission Rate in Optical Fiber Cable by Radiation

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1. Introduction

In order to enhance the safeguardability of Pyro-processing facility for spent fuel, it is important to prevent misuse of facility, so remote analyzing technology to monitoring the processing progress is required. Korea Atomic Energy Research Institute(KAERI) has studied the Fiber-Optic Laser-Induced Breakdown Spectroscopy(FO-LIBS) as one of the real-time monitoring technology to be applied processing facility. FO-LIBS is one of the elemental analysis methods to analyzing the composition of the sample which generates plasma by focusing on the sample surface with laser beam through an optical fiber and receives the fluorescence from LIP(Laser-Induced Plasma) through an optical fiber.[1,2] This technology is considered suitable method for real-time monitoring of processing facility since it has benefits of non-pretreatment and non-destruction of samples also it is easy to apply for dangerous facility.[3] However, radiation damage can arise when optical fiber and lenses for focusing the laser beam and receiving the fluorescence are exposed to radiation.[4] Thus, we have performed the radiation irradiation for optical fiber before the system is applied to the facility, based on this we analyzed the variation in optical characteristics of the optical fiber by radiation exposure and evaluated the eligibility of application to facility.

2. Experiments

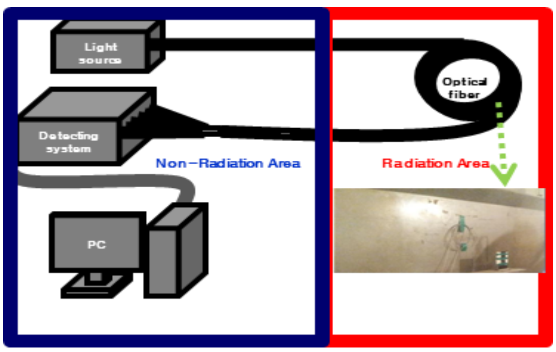

Fig. 1. Experiment diagram.

The experiment was performed on the high and low level irradiation device(KAERI Advance Technology Radiation Laboratory, Jeongup, Jeonlabukdo) with dose rate of 0 to 20 kGy/hr. The device used for the environment, public health, food, and basic research in the areas that require a high dose of gamma-ray through Co-60 gamma-ray. Figure. 1 is a diagram of the experiment. In the experiment, two types of optical fibers, FG365UEC, Thorlabs and Optran UV, Ceram optec, were used. The Thorlabs fiber is a component of FO-LIBS, the Ceram optec fiber is a radiation-hardened fiber and was used for comparison with this. The middle portion of optical fiber was positioned in radiation zone, and the connection portions at both ends were connected to the detection system(Aurora, Applied spectra) and deuterium/halogen lamp(Avalight-DH-S BAL, Avantes) positioned in non-radiation zone, respectively. Light generated from the lamp is transmitted to the detecting system. We expected that transmission rate will be changed depending on the degree of damage to the optical fiber.

3. Results

3.1 Performance verification of the detecting system and the light source

Before irradiating radiation to the optical fiber, performance verification of the detecting system and the light source was performed by obtaining precision. Repeated measurements of 11 times were carried out, we obtained RSD of 0.196%.

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3.2 Variation of transmission rate by gamma-ray irradiation

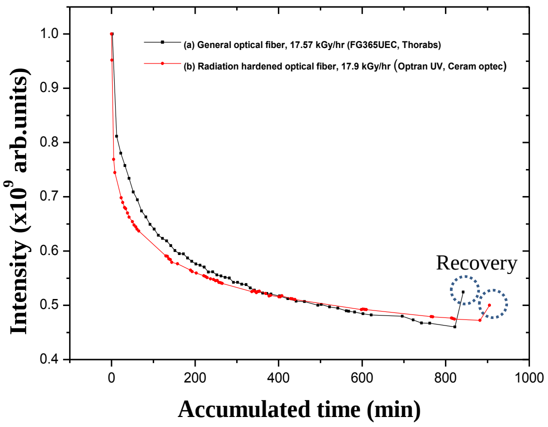

Fig. 2. Variation of transmission rate by high level gamma-ray
(a) Thorlabs FG365UEC, (b) Ceram optec Optran UV.

The transmission rate variation of the optical fiber is shown in figure 2, when it is irradiated with high level gamma-ray. The variation of transmission rate is indicated as sum of intensity of all wavelength region. Both were decreased rapidly in early irradiation time. Also they were decreased continuously with time, but a slight recovery was shown when leaving irradiation environment.

Figure 3 is a graph showing a transmission rate variation of each wavelength of optical fibers by irradiation. With the passage of time, Both of them were decreased in the all wavelength range, but the reduction is different depending on the wavelength. We could observe the phenomenon that transmission rate decreased rapidly at more shorter wavelength in early irradiation time. After about 10 minutes, transmission rate of common fiber and radiation-hardned fiber were changed to 1.9% and 7.6% in wavelength range of 190 to 300. But, in wavelength region of 900 to 1040 nm, it were varied to 106.0% and 103.0% respectively.

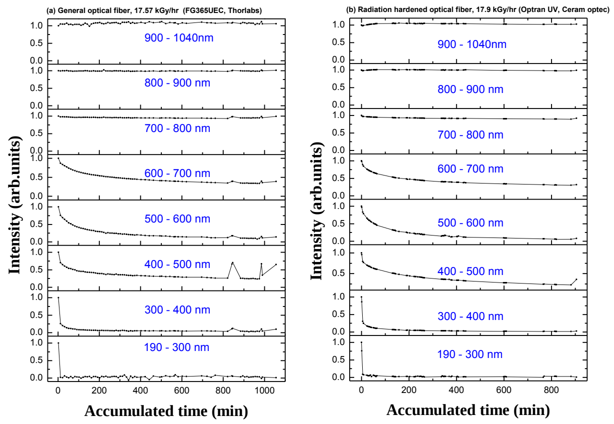

Fig. 3. Transmission rate variation of each wavelength of optical fibers by high level gamma-ray
(a) Thorlabs FG365UEC, (b) Ceram optec Optran UV.

3.3 Comparison of transmission rate variation by dose rate

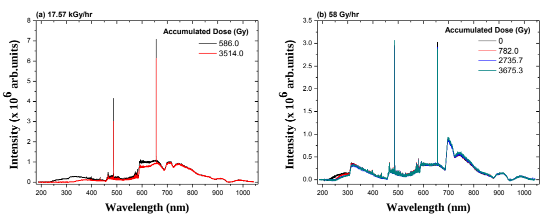

Fig. 4. Transmission rate of Thorlabs FG365UEC by dose rate variation
(a) 17.57 kGy/hr, (b) 58 Gy/hr.

We irradiated the low level gamm-ray on common optical fiber cable, and the transmission rate were compared with the results of high level gamma-ray irradiation.

The Transmission rate variation of optical fiber cable by dose rate is shown in figure 4. Despite of the same amount of radiation was irradiated, the variation of transmission rate in the low dose rate was less than the other. When the irradiation dose was about 3500 gray, the transmission rate of (a) was decreased to 81%, and (b) was unchanged. It means that momentary irradiation exposure of high level radiation more affects to damage of optical fiber than continuous exposure of low level radiation.

3.4 Setting of limit dose rate of the optical fiber cable

Most emission lines of uranium and plutonium to be monitored in processing facility is placed in the wavelength region of 300 to 500 nm. So it was necessary to set the limit dose rate in the wavelength range. The variation of transmission rate in wavelength range of 300nm to 500 nm is shown in figure 5. Despite the low level of the irradiated gamma-ray, as it goes to the short wavelength, the transmission rate was more decreased. In 600 Gy/hr or more, a considerable decrease of transmission rate was happened in 300 to 350 nm as well as other wavelength regions. When the dose rate was decreased to 540 Gy/hr from 600Gy/hr, the reduction of transmission rate was declined remarkably. In addition, it did not have much difference in the dose rate of 540 Gy/hr and 180 Gy/hr

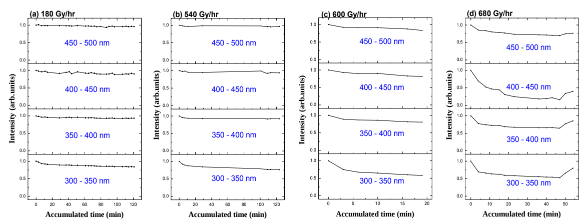

Fig. 5. Variation of transmission rate in wavelength range of 300 to 500 nm by dose rate
(a) 180 Gy/hr, (b) 540 Gy/hr, (c) 600 Gy/hr, (d) 680 Gy/hr.

4. Conclusions

Damage of the optical fiber by radiation exposure induced the decrease of transmission rate. Loss of the transmission rate in the short wavelength was much larger, the optical fiber had slight recovery at the same time as leaving in the radiation environment. Even if same dose is irradiate, momentary irradiation exposure of high level radiation more affects to damage of optical fiber than continuous exposure of low level radiation. We present that the limit dose rate is set to 500 Gy/hr by the transmission rate variation of wavelength region of 300 to 500 nm.

In further stuy, we will take into account for the effect of neutron on the optical cable.

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