Irradiation Effects of Electron Beam on Optical Fibers

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1. Introduction

The surveillance or monitoring systems used in space station, nuclear power plant and nuclear waste repository, are often equipped with optical fibers to remotely locating expensive camera systems so as to protect them from direct irradiation.

Especially in nuclear power plant and nuclear waste repository, irradiation by gamma-ray and beta-ray are most concerned.[1] The effective life-time of such surveillance system may depend on the soundness of the optical fiber because it is the component to be exposed the high intensity of radiation field by purpose.

Though the degradation of mechanical properties such as hardness and elasticity may occur but the degradation of the optical property such as spectral transmittance is the most possible cause of the effective life-time limitation. Generally 30 % reduction of light signal transmittance is considered as the life-time threshold point of such optical systems.

In this paper, we studied irradiation effects on spectral transparency of various commonly-used optical fibers with high energy electron beam to conveniently simulate the both gamma-ray and beta-ray irradiation situation.

2. Materials and Method

2.1. Optical Fibers

Six types of optical fibers were tested as shown in Table 1, where SMF, MMF, POF and HPCF mean Single Mode Fiber, Multi Mode Fiber, Polymer Optical Fiber and Hard Polymer Cladding Fiber respectively. These fibers are different in materials, radius, cutoff wavelength and mode. All the samples are 50 cm long.

Table 1. Optical fiber types

Type	Materials	Outer Radius [mm]	Cutoff wavelength [nm]
SMF HI1060	Fused Silica (SiO2)	< 0.1	1060
SMF HI1550	Fused Silica (SiO2)	<0.1	1550
MMF 50μm	Fused Silica (SiO2)	<0.1 (50μm multi)	-
MMF 62.5μm	Fused Silica (SiO2)	<0.1 (62.5μm multi)	-
POF	Polymer	<0.3	-
HPCF	Core : SiO2 Clad. : polymer	<0.2	-

2.2. Electron Beam Experiment

We used an electron accelerator, Model ELV-8, Eb-tech Inc. of which the maximum electron energy is 2.5 MeV and the maximum current is 50 mA.[2] Fig. 1 is schematic of electron beam system.

The selected electron energy was 1 MeV in order to represent the most common energy of gamma and beta-rays from radionuclides. The dose range was from 1 kGy to 1 MGy.

The electron dose from the electron accelerator can be calculated by the following equation.

$$D = a \times E \times I \times V \times N \quad (1)$$

where
D: radiation dose [kGy]
a: the correction factor depending on the sample thickness and density
E: the electron beam energy [MeV]
I: the electron current [mA]
V: the sample moving speed [m/min]
N: the number of irradiations

The correction factor, a, depends on the beam current, the sample thickness and the density. For example, if the density of optical fiber is 1 and the thickness is 0.3 mm, a = 0.023, 0.03 and 0.546 for I = 1.1, 16.7 and 18.3 respectively.

The test conditions are summarized in the Table 2.

Table 2. E-beam irradiation condition

	E [MeV]	I [mA]	V [m/min]	N	Dose [kGy]
1	1	1.1	20	2	1
2	1	1.1	20	10	5
3	1	16.7	20	1	10
4	1	18.3	5	1	50
5	1	18.3	5	2	100
6	1	18.3	5	4	200
7	1	18.3	5	10	500
8	1	18.3	5	20	1000

2.3. Light Transmittance Measurement

The irradiated optical fibers are tested by an optical spectrum analyzer (OSA) which analyzes spectral transmittance of 600 to 1700 nm wavelength using a white light source.

Fig. 1. Inside of electron beam accelerator

3. Results and Discussion

Fig. 2 shows measured spectral transmittance of a SMF HI1060 fiber. In the figure, the results are in error range. So, electron beam has no effect upon the SMF HI1060.

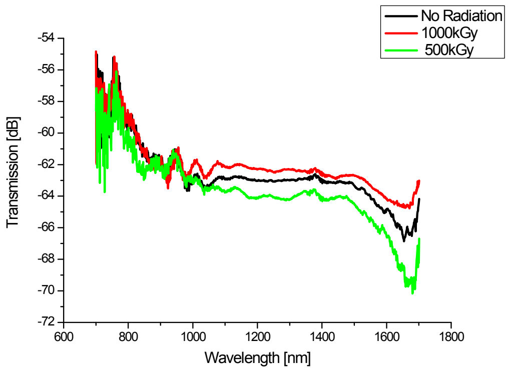

Fig. 2. Measured transmittance of SMF HI1060.

Fig. 3 shows the measured spectral transmittance of a MMF 50 μm sample. From this result, we can observe 2 things. Firstly, the irradiation of electron beam onto this multi-mode fused silica fiber significantly reduces the transmittance of light with wavelength below 750 nm. This explains an observed phenomenon which the output light is red when the input light is white. So the radiation damage in the glass may produce a defect which absorbs the blue and green component. Secondly, in the region of wavelength larger than 750, all the irradiated samples show a slightly lowered transmittance. However we could not see any systematic change in proportion to the radiation dose. This means all the changes due to the radiation is within the measurement error bound. So we need much longer samples to observe the accumulated dose effect.

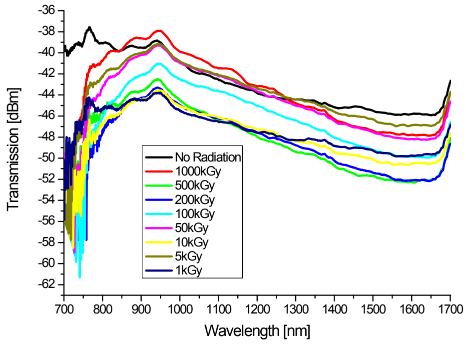

Fig. 3. Measured transmittance of MMF 50 μm. In this test, source is white light, but output light is red. The reason is that short wavelength light could not pass through irradiated optical fiber.

4. Conclusions

In this study, the electron beam was irradiated on optical fibers. There was no effect upon SMF HI1060, but the electron beam affect to MMF 50 μm sample. For more accurate results, longer optical fibers may be tested.

REFERENCES

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