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Feasibility Study of Development a Light Guide Using an SLA Based 3D Printer

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1. Introduction

In workplaces that use high-level radiation sources such as non-destructive testing, radiation workers always carry the risk of local radiation exposure accidents. When a local radiation exposure accident occurs, retrospective dosimetry is conducted to verify whether the exposed dose exceeds the permissible dose limit. However, current dose evaluation methods do not utilize customized anthropomorphic phantom that reproduces the accident conditions for retrospective dosimetry.

Therefore, a local skin dose evaluation system that uses 3D-printed plastic scintillator has been proposed [1]. The system measures the local exposure dose using a thin scintillator that imitates the basal layer of the skin. As this scintillator has a thickness of approximately 50 μm, it is expected to emit a small amount of scintillation photons. Therefore, the fabrication of a light guide capable of reducing the loss of scintillation is necessary. In this study, 3D-printed light guides that can minimize the loss of scintillation photons are fabricated and evaluated.

2. Methods and Results

2.1 Fabrication of Light Guide and Adaptor using 3D printing

The 3D-printed light guide was fabricated using an SLA-based 3D printer (Form 3, Formlabs) and a transparent resin (Clear V4, Formlabs). Two types of curved light guides and one type of flat light guide geometry were also designed. In addition, 3D-printed light guide samples were fabricated for experiments that compared the scintillation photon transmission performance of transparent resin and PMMA (Poly(methyl methacrylate)). The top and end surfaces of the light guides were polished and coated after fabrication for higher transparency.

An adaptor was also fabricated using the same 3D printer (Form 3, Formlabs) with white resin (White V4, Formlabs) to minimize the loss of scintillation photons. The fabricated light guide and adapter are shown in Figure 1.

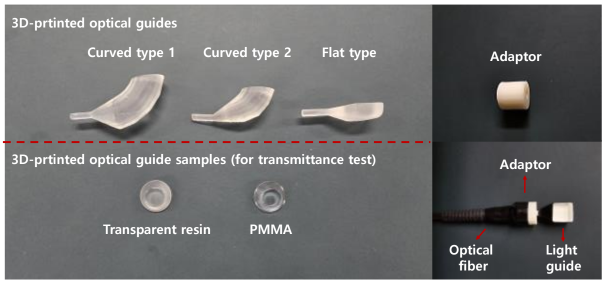


Fig. 1. 3D-printed light guides, adaptor and optical fiber connection

2.2 Transmittance measurement of Light Guide Materials

The experiments measuring the transmittance of the transparent resin and PMMA light guide samples were conducted using a UV/VIS spectrometer (LAMBDA 650S, PerkinElmer) and a 300 to 800 nm wavelength range of light. Since the maximum emission wavelength of the scintillator was 470 nm [2], the transmittance of each light guide sample for the corresponding wavelength was compared.

The transparent resin exhibited a transmittance difference of 1.59% at 470 nm wavelength compared to PMMA. Therefore, it was deemed that transparent resin could be used as a light guide fabricating material, considering the difference of transmittance. The measurement results are shown in Figure 2.

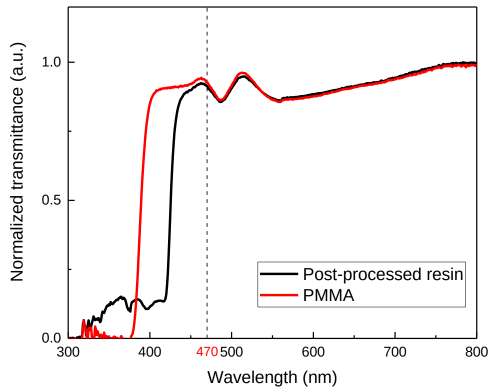


Fig. 2. Transmittance measurement result of each light guide material

2.3 Evaluation Transmit Efficiency by Light Guide Geometry

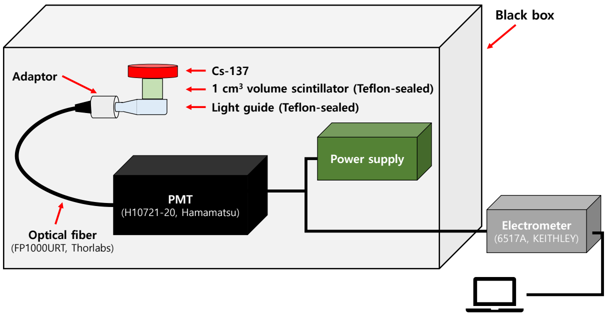
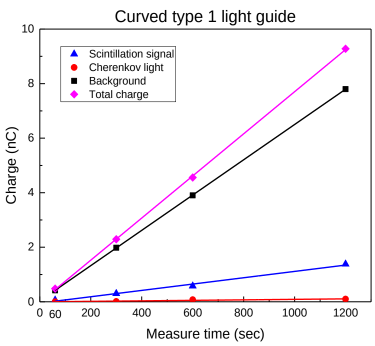


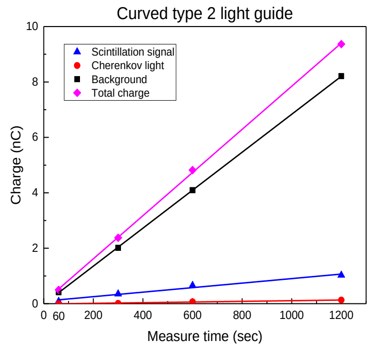
Fig. 3. Schematic diagram of a 3D-printed light guide evaluation system using 1cm^3 volume 3D-printed scintillator

The efficiency of each 3D-printed light guide was evaluated with an experimental system shown in Figure 3. The accumulated charge data over time was obtained from a 3D-printed plastic scintillator with 1 cm³ volume, which was exposed to a Cs-137 radiation source (9.55 μCi). The differences between the background and scintillation signal became more distinct as the measurement time increased.

In contrast to the previous experiment [1], the Cherenkov light signal was comparably small. This phenomenon can be attributed to the constrained generation of Cherenkov light within the limited confines of the light guide's small volume and to the inherent absorption by the optical fiber.

The evaluation results in Figure 4 illustrate the curved type 1 light guide have the most background and scintillation signal difference. Therefore, the curved type 1 light guide would be feasible to apply in a local dose evaluation system. In future research, the 3D-printed light guide will be optimized to measure the scintillation signal emitted from the basal layer imitated scintillator [1].





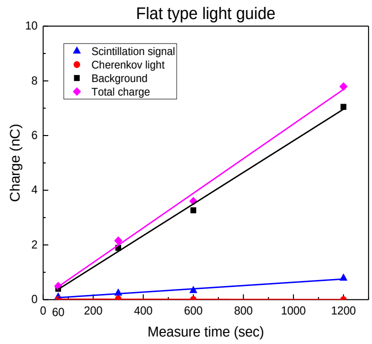


Fig. 4. 3D-printed light guide efficiency evaluation results

3. Conclusions

In this study, a 3D-printed light guide was designed to reduce the loss of scintillation photons. The light guides were fabricated using transparent resin and post-processed to enhance transparency. Although the light guides composed of transparent resin only showed a difference of 1.59% in transmittance compared to PMMA light guides, they were sufficiently acceptable considering the application environment (using customized phantom) and material properties. The efficiency of each light guide revealed curved type 1 light guide has the highest efficiency.

In the future, by integrating the scintillation signal transport system with the proposed light guide, the local dose evaluation system can be utilized as an auxiliary method in retrospective dosimetry.

REFERENCES

[1] Han Cheol Yang et al., "Development of a 3D－Printed Skin Imitation Layer for Localized Radiation Dose Evaluation.", Trans. of the Korean Nuclear Society Autumn Meeting. 2023. p. 1-2

[2] Kim, Dong Geon, et al. "Enhanced characteristics of 3D-Printed plastic scintillators based on bisphenol fluorene diacrylates." Radiation Physics and Chemistry 198 (2022): 110255.

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