

## Performance of 3D Printing Plastic Scintillator by Applying OLED Wavelength Shifter

Dong Geon Kim, Sangmin Lee, Yong Hyun Kim, Seung Jin Seon, Yong Kyun Kim\*  
Department of Nuclear Engineering, Hanyang University, Seoul(04763), Korea  
\*Corresponding author: ykkim4@hanyang.ac.kr

### 1. Introduction

Recently, 3D printing additive manufacturing technique has been applied to studies on the fabrication of different type of scintillator such as plastic scintillator (PS) and inorganic crystalline scintillator by adding UV-sensitive material and photo-initiator to scintillating components [1, 2]. This additive manufacturing technique has an advantage that a PS can be manufactured in an innovatively short time (10 minutes to 4 hours) as compared with the conventional thermal polymerization technique of several weeks.

In this study, we investigated the applicability of OLED wavelength shifter as a new wavelength shifter by measuring characteristic wavelength spectra. Hereafter, the scintillation performance was analyzed with the amount of OLED wavelength shifter in terms of relative light yield and light output. Additionally, we confirmed the improvement of scintillation performance by adding the diluent, Naphthalene. Relative light yield was measured using Cs<sup>137</sup> gamma source, and relative light output was calculated by applying the effective quantum efficiency.

### 2. Methods and Results

#### 2.1 OLED Wavelength Shifter

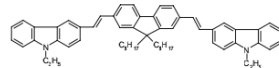
Wavelength shifter, one of the scintillating components (monomer, primary dye, and wavelength shifter) has characteristic wavelength spectra (absorption and emission). When a scintillator is irradiated from a radiation source, a series of successive energy transfer works through absorption and emission mechanism from monomer to wavelength shifter, and finally the scintillator emits characteristic fluorescence lights.

In this study, we selected OLED wavelength shifter, ADS086BE, and compared the conventional wavelength shifter, POPOP, to analyze the effect of wavelength shifter on scintillation performance. The properties of the OLED wavelength shifter ADS086BE (American Dye Source) are shown in Table 1.

To determine whether the selected OLED wavelength shifter is suitable for sensitive region of photomultiplier (PMT)'s photocathode, the emission wavelength spectra of both wavelength shifters were measured. The spectra were measured by using a Cary Eclipse Fluorescence Spectrometer (Varian), and the photomultiplier (PMT) with PSs was H6410 (Hamamatsu). Figure 1 shows the emission wavelength spectrum of each scintillation component. It is confirmed that the emission wavelength

spectrum of ADS086BE matches to the PMT's sensitive region like that of POPOP.

Table 1. Chemical and physical properties of OLED wavelength shifter ADS086BE.

<b>Chemical Name</b>	2,7-Bis-[2-(9-ethylcarbazol-4-yl)-vinyl]-9,9-dihexyl-9H fluorine
<b>Chemical Structure</b>	
<b>Melting Point</b>	214.20 °C
<b><math>\lambda_{max}</math> Absorption</b>	397 nm (THF)
<b><math>\lambda_{max}</math> Emission</b>	439, 463 nm (THF)
<b>Purity</b>	99.42%

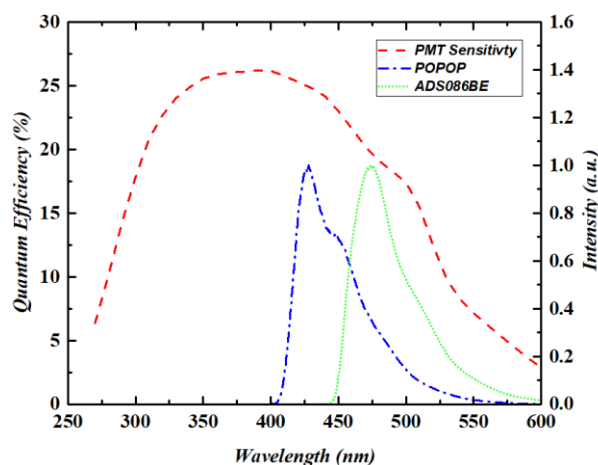


Fig 1. PMT's photocathode sensitivity and emission wavelength spectrum of both wavelength shifters (POPOP and ADS086BE)

#### 2.2 PS Formulation & Fabrication

An UV-polymerizable resin formulation was designed by adding photo-initiator to scintillation components to fabricate PSs with 3D printer. Table 2 shows a list of scintillation components and resin formulations used in the fabrication of scintillators. Each resin was stirred for 20 minutes in a water bath at 70°C. In case of resin with POPOP, the resins were stirred for 2.5 hours because of its low solubility rate. Pico2 HD DLP 3D printer (ASIGA) was used, and the size of the fabricated scintillators is 20 × 20 × 10 mm<sup>3</sup>

### 2.3 Scintillation Performance Evaluation

For evaluating scintillation performance of the fabricated PS, relative light yield was measured to commercial plastic scintillator BC408 (Saint Gobain) with Cs<sup>137</sup> gamma source following the method of Bertolaccini et al. [3]. Additionally, light output was calculated by applying for effective quantum efficiency according to the emission characteristics of PSs having different wavelength shifters, POPOP and ADS086BE. Effective quantum efficiency  $Q.E_{eff}$  and light output is calculated by the following equations.  $S$  is a radiant sensitivity of PMT's photocathode (Hamamatsu H6410) and  $I(\lambda)$  is emission intensity [a.u.] of characteristic fluorescence lights emitted from PS.

$$Q.E_{eff} = \frac{\int I(\lambda) \times Q.E.(\lambda) d\lambda}{\int I(\lambda) d\lambda}$$

$$\text{Light output} = \frac{\text{Light Yield}}{Q.E_{eff}}$$

The next two tests were performed to analyze the scintillation performance of the fabricated PS in this experiment (Table 2). At Test 1, the changes of scintillation performance with the amount of ADS086BE was evaluated as compared with POPOP. Figure 1 shows the performance of PS fabricated in Test 1. Effective quantum efficiency decreases with the amount of ADS086BE. PS with ADS086BE 0.03% shows the highest light yield 33%, while PS with ADS086BE 0.005% shows the highest light output 40.1% when applied for effective quantum efficiency.

At Test 2, the effect of Naphthalene which acts as a diluent for improving scintillation performance was evaluated. Figure 2 shows the scintillation performance of PS fabricated in Test 2. Effective quantum efficiency increases with the amount of Naphthalene. PS with Naphthalene 25% shows the highest light yield 40% and light output 51%.

### 3. Conclusions

We demonstrated an approach to applying OLED wavelength shifter to PS fabrication in terms of scintillation performance. The characteristic emission spectrum of ADS086BE was compared with that of the conventional wavelength shifter POPOP. Scintillation performance of the fabricated PS with ADS086BE was better than that of PS with POPOP. And the highest light output (51%) was achieved by adding Naphthalene as a diluent.

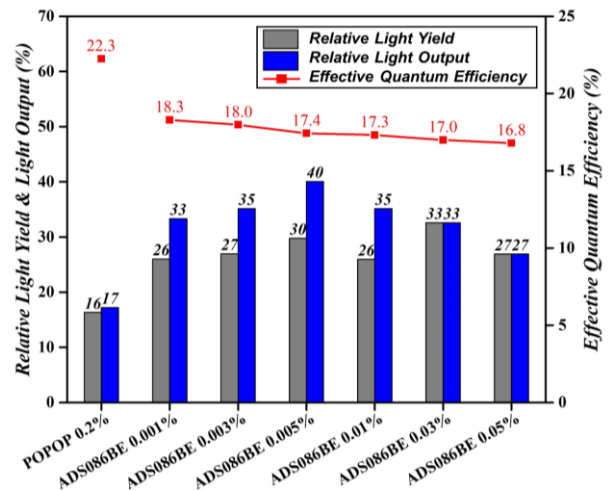


Fig 2. Relative light yield, relative light output and effective quantum efficiency of the fabricated PS in Test 1.

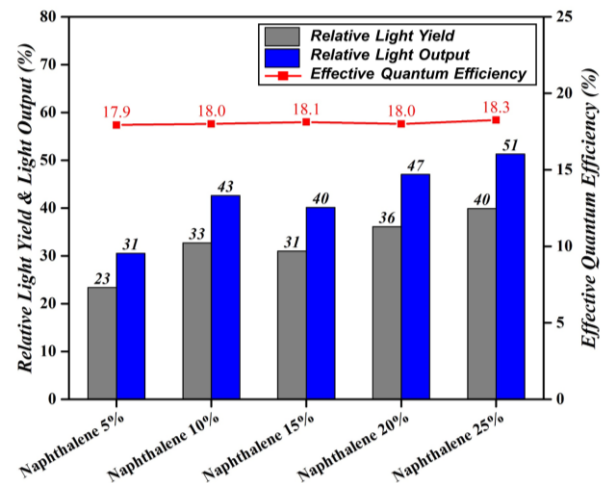


Fig 3. Relative light yield, relative light output and effective quantum efficiency of the fabricated PS in Test 2.

### REFERENCES

- [1] Y. Mishnayot et al., "3D Printing of Scintillating Materials", arXiv preprint arXiv:1406.4817, The Royal Society of Chemistry, 2014.
- [2] G. A. Dosovitskiy et al., "First 3D-printed complex inorganic polycrystalline scintillator", 2017.
- [3] M. Bertolaccini, S. Cova, C. Bussolatti, in Proc. Nucl. Electr. Symp. Versailles, France, 1968.