Disinfection of Phytoplankton by Application of UV LED

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Abstract: Ship ballast water includes variety of marine species in the port or near coast. When ships come in and/or out port, discharged ballast water contaminates sea and destroys marine ecology system. The International Maritime Organization(IMO) adopted the convention on ballast water management in February 2004 and insists all ships be equipped with ballast water treatment system from 2010.

In this paper, we analyzed disinfection characteristics for phytoplankton using deep Ultra-Violet Light Emitting Diode(UV LED) as a basic study for developing ballast water treatment system. We fabricated UV LED modules having peak in wavelength at 255, 265, 280 nm and exposed each module to equal UV dose between 100~400 mJ/cm2. The experimental result showed that the highest disinfection wavelength on the phytoplankton appeared at 265 nm when equal UV dose was irradiated.

Key-Words: UV LED, Phytoplankton, Disinfection, Wavelength, Ballast water

1 Introduction

Ballast water is sea water filling a ship to maintain its balance, and annually about 10 billion tons of ballast water with organisms such as plankton, germs and bacteria is being transported around the world and they cause diseases and contamination of marine ecology[1]. With this background, IMO adopted regulations for ship's ballast water treatment in February 2004 and suggested all ships should gradually get equipped with BWTS from 2010[2].

Currently, methods using filtration, ultraviolet, ozone and electrolysis are under progress for treating ballast water and UV treatment which is one of them has the advantage of having no remaining toxic and DBPs(disinfection by products)[3].

Low-pressure and medium-pressure UV lamps are mainly used in recent UV treatment, however, explosion-proof and safety should be concerned since these methods have high power consumption rate and use high voltage. On the other hand, UV LED has low power consumption rate and applied current of 10 to 100 mA, and disinfection efficiency can be raised because UV LED can selectively irradiate monochromatic wavelength in UV-C.

Therefore, we designed and fabricated UV LED modules to analyze disinfection characteristics of UV LED with wavelength ranges of 255[nm], 265[nm] and 280[nm] on phytoplankton such as Tetraselmis sp.

2 UV LED system

2.1 UV LED

A device based on AlN, ZnO, GaN of direct band gap structure to develop UV LED is under development, having wavelength ranges of 200 to 400 nm. Among these ranges, ranges of 200 to 300 nm are well known as disinfection wavelength, transforming the structures of DNA and RNA to microorganisms.

In this paper, UV LED having peak wavelength in ranges of 255[nm], 265[nm] and 280[nm] was used to analyze the disinfection characteristics of phytoplankton in accordance with UV wavelength.

Table 1 shows specification of the UV LED used in experiment. The forward voltage differs depending on wavelength range of UV LED when the applied voltage is fixed at 20 mA.

<table>
<thead>
<tr>
<th>Wavelength [nm]</th>
<th>255</th>
<th>265</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward Voltage [VDS]</td>
<td>7.3</td>
<td>6.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Current [mA]</td>
<td>20</td>
<td>20</td>
<td>20</td>
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</tbody>
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2.2 UV LED module

Fig. 1 shows the fabricated UV LED module. This module consists of metal PCB to emit heat from LED and 40 UV LEDs are arranged in a raw, and zener-diode is paralleled with UV LEDs for protecting the device.
2.3 Module driver

Driving by the control of constant current should be required because the device might be destroyed or its function may get lowered when move current than allowed is applied. For safe driving of UV LED, a circuit controlling constant current was fabricated as shown in Fig. 2.

The constant current characteristics of the fabricated UV LED driver are as presented in Fig. 3 and it can determine the $V_{DS}$ of the LED, and the output of constant current when $R_{ext}$ is controlled.

3 Experiment

3.1 Spectrum Analysis

To analyze the optical spectrum characteristics of the fabricated UV LED modules, a spectrometer (Avaspec-3648/Avantes) was used. Result of spectrum analysis presented in Fig. 4 and the UV LED modules used in experiments show the peak wavelength at 255[nm], 265[nm] and 280[nm] respectively and approximately 10[nm] of FWHM (full width at half maximum).

Because the UV LED has characteristics of monochromatic wavelength which does not show spectrum in ranges except for the above, selective UV irradiation is possible.

3.2 UV intensity analysis

For the equal irradiation rate, each UV intensity of the fabricated UV LED modules was analyzed using the UV power meter (HD2102/Deltaohm). Fig. 5 presents the UV intensity of used UV LED modules with 255[nm], 265[nm] and 280[nm].
Because each module had different UV intensity, we changed the irradiation time to get the equal amount of irradiation.

\[ UV \text{ dose} = I \times t [\text{mJ/cm}^2] \]  

3.2 Analysis of disinfection characteristics

To analyze the disinfection characteristics of the UV LED modules, the experiment was set up as shown in Fig. 6. The culture fluid of *Tetraselmis* was placed 1 cm below the UV LED module, and energy of 100 to 400 [mJ/cm²] was irradiated into each specimen.

Fluorescent microscope as shown in Fig. 7 was used to determine and calculate the number of disinfected phytoplankton and the disinfection characteristics were analyzed by comparing the number of plankton immediately before/after and five days after the experiment.

4 Results

Fig. 8 shows the shape of *Tetraselmis* before and after UV treatment. While *Tetraselmis* showed its round cell membrane clearly before UV treatment, the shape of the cell membrane was transformed afterwards.
Fig. 9 shows disinfection rate of *Tetraselmis* in accordance with irradiated energy for each UV LED module. The result showed that the more the energy was irradiated, the higher the disinfection rate appeared. Each module shows different disinfection rate; 89–93[%] in 265[nm]; 68–75[%] in 280[nm]; and 76–80[%] in 255[nm] module. Resultantly, in the case of *Tetraselmis*, valid disinfection area is formed within the wavelength of UV-C, and especially between 260 and 270[nm] appeared the highest disinfection rate.

Fig. 10 shows the disinfection rate of each module on the day and five days after the experiment was conducted. The disinfection rate measured after five days appeared higher than that of the experiment day. We regard it is due to the destruction of DNA and suppression of cell multiplication by UV.

### 5 Conclusion

This paper described the analysis of disinfection characteristics of UV LED on phytoplankton. From the experimental result, the disinfection rate appeared the highest in UV LED module of 265[nm]. The disinfection rate measured after five days appeared higher than that of the experiment day. We regard it is due to the destruction of DNA and suppression of cell multiplication by UV rays. The experimental result shows that *Tetraselmis* has the highest absorption rate within 260–270[nm] which is in accordance with the
report that DNA of cells absorb wavelength within 260[nm], the UV-C, well. It appeared the most efficient to use the UV LED of 265[nm] for disinfecting *Tetraselmis*, a phytoplankton, with the equal amount of UV irradiation.

Studies on the periodic disinfection efficiency, however, are required since the UV light intensity differs depending upon the sort of UV LED.

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**References:**


