Crude Oil Detection using CMOS Image Sensor and UV LED

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Abstract—**Crude oil detection in the sea is an important task for the prevention of oil spill and the oceanic environment management. To measure the crude oil which is dissolved in the seawater, a sensor based on the fluorescence spectroscopy is widely used, because it is made up of hydrocarbon compounds. However, most of these sensors use an ultraviolet mercury lamp, several optical filters, and the photomultiplier tube (PMT). These components make the sensing platform large and expensive. To address these issues, we have developed the fluorometer, which is composed of optical devices having cost effectiveness and compact size, such as complementary metal-oxide-semiconductor (CMOS) image sensor and ultraviolet (UV) light-emitting diode (LED). In this paper, we provide the sensing platform, the principal sensing mechanism and the test results, which were obtained by an experiment using two different crude oils. Through these results, we can show the sensing performance of our novel fluorometer for the detection of crude oil.**

Keywords-crude oil detection; fluorometer; in-situ sensor; CMOS image sensor; UV LEDs.

I. Introduction

Contamination evaluation of oil spilled in sea water is a critical step in the procedures of ocean recovery. To this end, a number of sensing systems have been developed to assess the degrees of the residual contaminants in the sea water [1][3][5][6][7]. Among those various sensing modalities, the fluorescence spectroscopy based system has been widely accepted because it can precisely quantify the concentration of total petroleum hydrocarbons (TPHs) which is a mixture of toxic chemicals originated from crude oil [2][4][8].

The main components of the fluorescence spectroscopy system are an ultraviolet (UV) light source, e.g., UV mercury lamp, the monochromator, multiple excitation/emission filters, and a photomultiplier tube (PMT) optical sensor. However, those key components of the fluorescence spectroscopy make the system often expensive and bulky, limiting the widespread use of the fluorescence sensing system especially for the sea water monitoring.

In this work, we introduce a compact and cost-effective fluorometer which is only composed of compact and low-cost optoelectronic components such as complementary metal-oxide-semiconductor (CMOS) image sensor, i.e., ~14 USD per chip, and UV light-emitting diode (LED), i.e., ~5 USD per chip.

In this paper, we will provide the design of our sensing platform, the principal sensing mechanism and the test results, which were obtained by an experiment using two different crude oils.

II. Materials and methods

To demonstrate the performance of this simple fluorometer, two different crude oils from Iraq and Russia were utilized. Figure 1 shows the schematic representation and experimental setup of our proposed compact and cost-effective fluorometer. The main characteristic of the proposed system is to employ the CMOS image sensor and UV LED for its sensor and light source. Since the CMOS image sensor has more than 5 mega pixels, corresponding to the same numbers of the sensors, variation of the fluorescence measurements was much smaller than that of the PMT, an expensive high-end single pixel photo-detector most widely accepted by oil spilled sea water detection systems commercially available.

III. Results and Discussion

Figure 2 shows the oil detection performance of the proposed system. To determine the limit of detection (LOD) of the proposed system, each oil sample was diluted by hexane solutions ranging from 1,000 ppm to 100 ppb and the measurements were triplicated at each concentration. In Figure 2, the averaged pixel intensity at each concentration has been calculated to plot the sensorgram. Figure 3 shows the raw digital images of the fluorescence emission from the various concentrations of the crude oils, captured by the CMOS image sensor.

With this result, we can draw the dynamic detection range of the proposed sensing platform. In the case of Russian crude oil, it has a linear detection range from 1 ppm to 1000 ppm, whereas, in the case of Iraqi crude oil, the light intensity acquired by CMOS image sensor was saturated between 100 ppm and 1000 ppm. Thus, the dynamic detection range of that case is from 1 ppm to 100 ppm. Through these two experiments, we can see that the amount of TPHs in Iraqi crude oil is more than that in Russian crude oil.

 ISBN: 978-1-61208-494-7

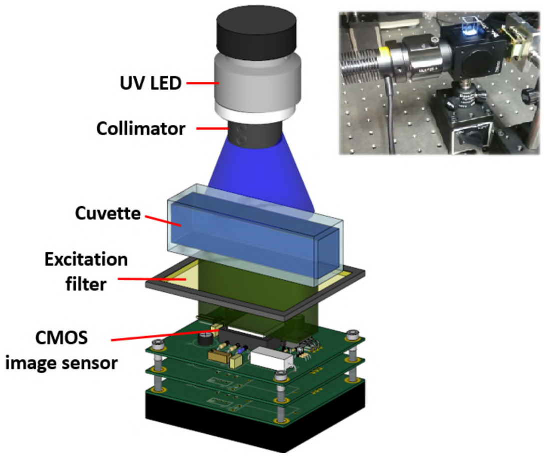

Figure 1. Schematic diagram and experimental setup of the proposed compact and cost-effective fluorometer.

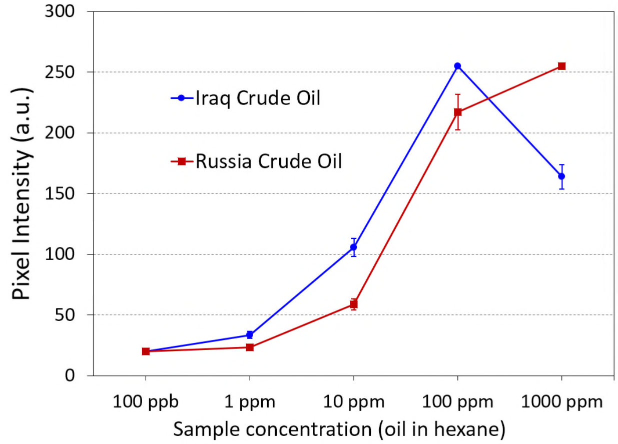

Figure 2. Fluorescence based oil detection results of the proposed system for crude oils from Iraq and Russia.

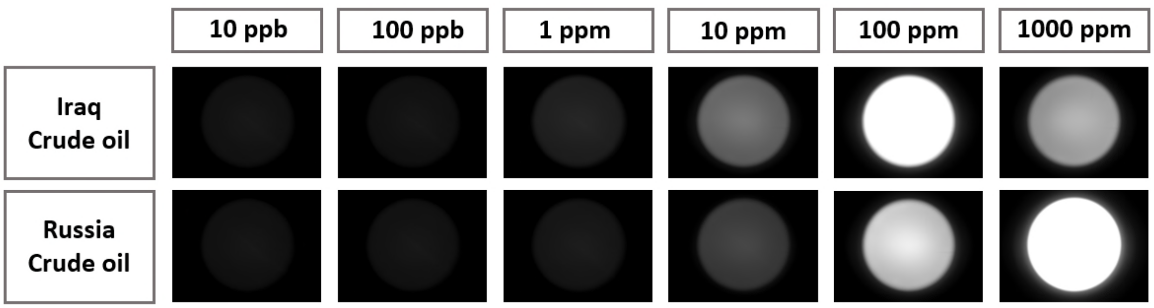

Figure 3. Raw CMOS images of the fluorescence emission from the various concentrations of the crude oils.

IV. CONCLUSIONS

In summary, a compact and cost-effective fluorometer using UV LED and CMOS image sensor for crude oil detection was proposed and demonstrated. According to the experimental results, the LOD of the proposed simple system was ranging from 1 ppm to 100 ppm or 1,000 ppm, which is comparable to that of a commercial fluorescence spectroscopy system, i.e., TD-500D (Turner Designs Hydrocarbon Instruments, USA). In this presentation, we will also discuss another experimental protocol that can push the LOD of the proposed system down to ~10 ppb.

ACKNOWLEDGMENT

This work was supported by the Korea Research Institute of Ships and Ocean Engineering (KRISO) Endowment-Grant (PES2240).

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