NOVEL OPTICAL SENSING SYSTEM BASED ON WIRELESS PAIRED EMITTER DETECTOR DEVICE FOR LAB ON A DISC WATER QUALITY ANALYSIS

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ABSTRACT

This work describes the first use of a wireless paired emitter detector diode (PEDD) as an optical sensor for water quality monitoring in a lab-on-a-disc device. The microfluidic platform, based on a pH dye/ionogel sensing area combined with a low-cost, wireless optical sensor, PEDD, is applied for monitoring the pH and the degree of turbidity of water samples in real time. Calibration of the system resulted in a linear response that obeys the Beer-Lambert Law. A reasonable correlation between water pH results obtained using the PEDD system and a standard pH-meter was obtained.

KEYWORDS: Light emitting diode, optical sensor, lab-on-a-disc, ionogel

INTRODUCTION

Typical analysis methods are very costly and time consuming, therefore simple, rapid, accurate, cost-effective field-deployable sensors incorporating wireless communication capabilities need to be developed [1, 2]. The main requirements of these sensors such as reproducibility, low cost as well as selectivity and sensitivity must be met for scale-up and mass fabrication allowing for real-time monitoring as well as widespread field deployment.

In this paper, a novel microfluidic platform, based on a pH dye/ionogel sensing area (Fig. 1) and combined with a low-cost, wireless optical sensor, PEDD, is applied for monitoring water quality in real time. So far, environmental water quality analysis has been provided by standard lab-on-a-chip systems [3], but not by centrifugal disc (CDs) platforms, which offer many advantages such as the elimination of large power supplies and external pumps [4]. The PEDD system, involving two light emitting diodes placed above and below the sensing area, is portable, incorporates wireless communication and is completely sustained via a small lithium polymer battery. In terms of microfluidics, the non-contact PEDD detection scheme aligns perfectly with centrifugal Lab-on-a-disc systems, which can have difficulties in monitoring during rotation [5].

MATERIALS AND METHODS

The CD was designed for multi-parameter water analysis, containing large chambers with several sub-compartments for various functions (Fig. 2a). An upper section, restricted by the thin Pressure Sensitive Adhesive (PSA), creates a microfluidic sieve capable of trapping large debris (>85 μm) during centrifugation. The sieve opens over the two sensor areas with photopolymerized ionogels, the blank, and the sensor with a pH sensing dye (Bromocresol Purple (BCP)). The BCP exhibits a characteristic color change depending on the pH of the solution, which can be detected by the light emitting diodes due to the light dependant discharging process. Finally the microfluidic area tapers to a secondary sedimentation area for analysis of smaller particulates (<85 μm). The PEDD system consists of two light emitting diodes, one of which acts as a light source, while the other, reverse biased, serves as a detector. In order to measure the time taken for the photocurrent generated by the emitter LED to discharge the detector one from 5 V, logic 1, to 1,7 V, logic 0, a simple timer circuit is used. At the same time the device allows for a digital output omitting an operation amplifier or A/D converter. A USB/XBee socket sends data to a laptop in real time via Bluetooth, Figure 2b. A custom designed PEDD holder for Lab-on-a-Disc applications allows easy rotation of the disc as well as accurate measurements.

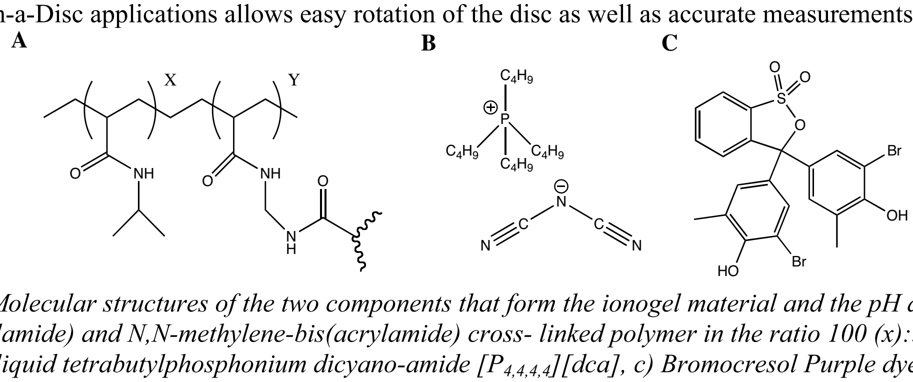

Figure 1: Molecular structures of the two components that form the ionogel material and the pH dye. A) poly-(N-isopropyl- acrylamide) and N,N-methylene-bis(acrylamide) cross- linked polymer in the ratio 100 (x):5 (y) b) the ionic liquid tetrabutylphosphonium dicyano-amide [$P_{4,4,4,4}$][dca], c) Bromocresol Purple dye.

a) b)

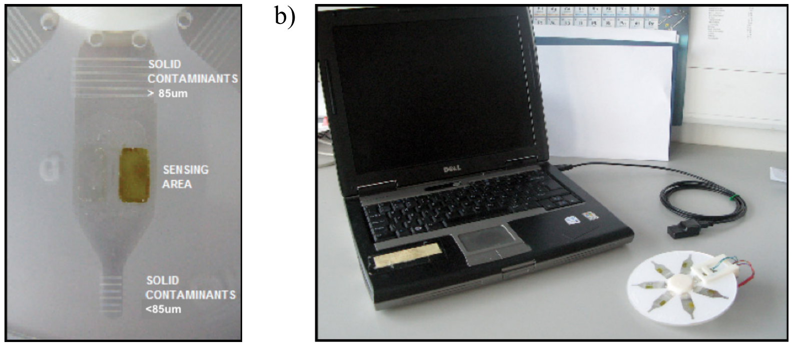

Figure 2: a) Channel consisting of three chambers b) prototype of the PEDD centrifugal micro-fluidic system.

EXPERIMENTAL

Firstly, the calibration of the system was performed using standard buffer solutions. Then real samples from the River Tolka, Dublin (Ireland) were collected from nine different locations (Fig. 3). To provide references, samples were measured using standard pH-meter for control, whereas the turbidity was examined with standard UV-VIS spectrometer. Then, after loading 100 μL of the samples in the upper chambers, the rotor was placed on a spin stand. Spinning the CD at 1500 rpm forced the liquids towards the bottom chamber. The dye reacted with the samples, which resulted in color change of the sensing area. Next, the measurement was carried out using the PEDD detection system in a dark environment, to reduce external light noise. The light dependence discharge time of detector LED was measured continuously for 30 seconds.

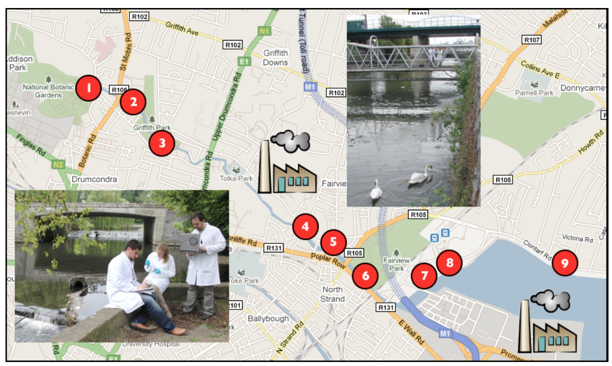

Figure 3: Map of the river Tolka and the sampling points (red dots).

RESULTS AND DISCUSSION

Calibrating the sensor resulted in a plot shown in Figure 4a. The sensor responded to pH change of buffer solutions, resulting in different discharge times of the detector. Four images of the liquid movement from the upper section towards the bottom chamber, taken in the real time, are showed in Figure 4b.

a) b)

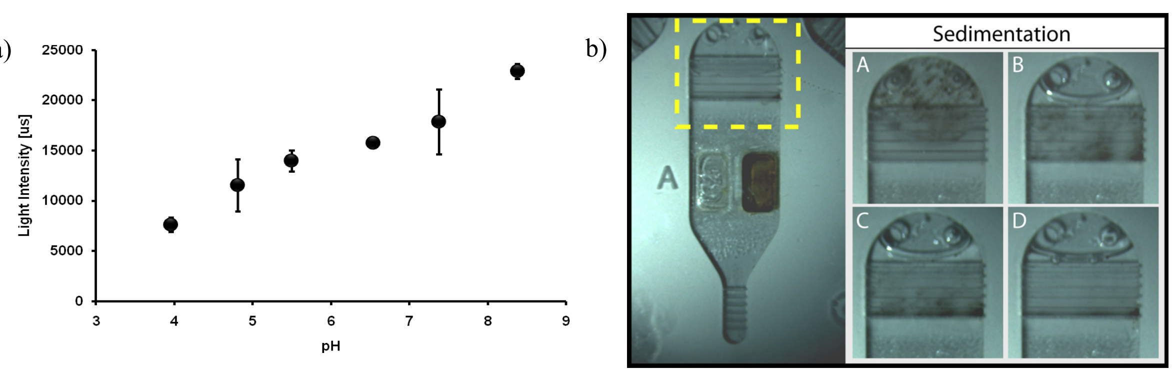

Figure 4: a) Calibration curve of the sensing area of the microfluidic device using pH buffer solutions. (n=70, error represents the average of light intensity values during data collection). b) Images of a channel of the CD-chip during centrifugation at 1500 rpm. A) the upper chamber is filled with sample, then the disc is spun for two minutes and all the liquid is transferred to the sensing area (B-D). Solid contents are accumulated in the first chamber (>85μm diameter) (B-D) and at the bottom of the channel (<85μm diameter).

The sensing area changed color according to the water pH and the solids in water were separated in the upper chamber and accumulated in the bottom chamber by their size as mentioned above. Figure 5 shows a reasonable correlation between pH results obtained using the PEDD system and a standard pH-meter. In the case of turbidity, although the samples contained low solid contents, it was possible to separate them from the sensing area, Figure 6.

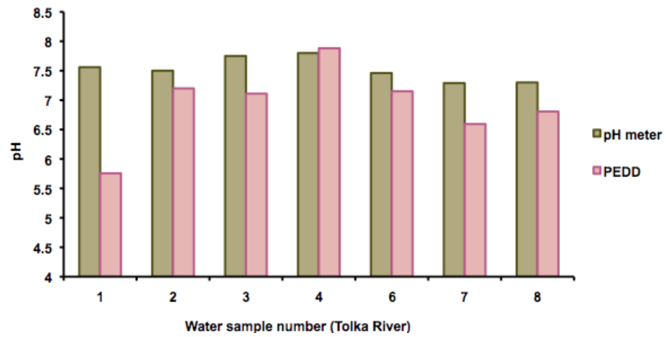

Figure 5: Water pH analysis using a commercially available pH-meter and the PEDD lab-on-a-disc device.

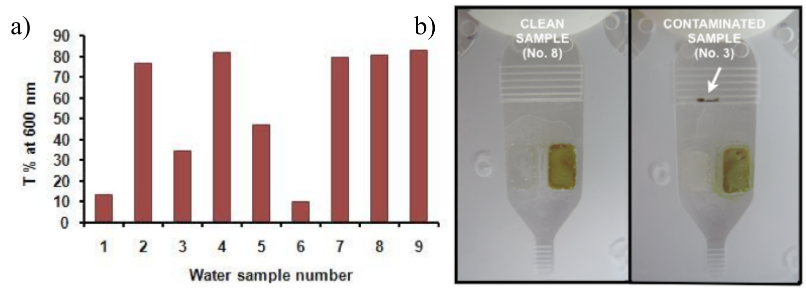

Figure 6: a) Turbidity measurements using a UV-VIS spectrometer (transmittance) and b) two channels with river samples; one is clean (left) while the other contents solids in the upper chamber (right).

CONCLUSION

A novel optical sensing configuration for lab-on-a-disc water quality measurements applications has been developed. Instrumentation incorporates low power detection coupled with wireless communication and power supply onto Lab-on-a-disc system. The CD designed for multi-parameter water analysis allowed not only for pH measurement, but also the solid contaminants test of the sample We believe that this device will be of special interest in samples with a relatively high level of solid contaminants that could interfere with optical analytical measurements.

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