The assay of anionic surfactant employing thread based analytical device with mobile phone

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Abstract

Thread based analytical device as an analytical platform with mobile phone has been developed as green chemical analysis for the assay of anionic surfactant. The platform involves microfluidic behavior. The thread composing a bunch of cotton fibers could serve as channel that allows anionic surfactant to move along. The part of the thread containing anionic surfactant could be seen blue when threated with methylene blue while the part without anionic surfactant showed no blue. The platform could be then photo taken. A plot of log value of concentration of anionic surfactant versus the move distance along the thread exhibits linear: $y = 129x + 371$; $r^2 = 0.999$ where x being log (SDS concentration) and y being distance.

Keywords thread based analytical device, microfluidics, mobile phone, green chemical analysis, anionic surfactant

1. Introduction

Anionic surfactants have been used for various purposes, commonly used in daily life including detergents and washing products. [1,2].

Various analytical techniques have been applied to determine anionic surfactants such as titration [2], chromatography [3], sensor-based methods [4], and liquid-liquid extraction [5,6]. The standard method, which is commonly and widely used is the spectrophotometric method, so called "Methylene blue (MB) method". It involves solvent extraction based on ion pair formation by the anion surfactant and the Methylene blue (MB) cation. The intensity of blue color was measured at 652 nm. [1,7]. However, these techniques have some drawbacks for example large quantities of solution (tens or hundreds of milliliters) and organic solvent. Flow based techniques, namely flow injection analysis (FIA)[8], and sequential injection analysis (SIA) with lab-at-valve (LAV) [9] have been developed, by our group, for down scaling solvent-solvent extraction of the determination of anionic surfactant using MB were reported. There were some drawbacks due to some toxic organic solvents and complicate instrumentation.

Recently, thread-based sensors have been developed, as mostly for low-cost clinical diagnostic applications [10-17]. It would be observed that it is without external pumping. Thread could be used to generate channels. It could serve as simple, rapid and portable device. Everyday life modern information technology devices, including mobile phone have been incorporated for chemical analysis [18].

Here, we report down scaling, without solvent extraction, the assay of anionic surfactant using thread based analytical device with the use of mobile phone.

2. Experimental

2.1 Chemicals and Reagents

Analytical grade chemicals and deionized water were used in this work.

Sodium dodecyl sulfate (SDS), anionic surfactant, was from Sigma-Aldrich and prepared for a stock solution (5,000 mg/L) by dissolving 0.5000 g in water and was made up to 100.00 mL volume.

A stock methylene blue solution (0.0934% w/v) prepared by dissolving 0.0934 g of the solid (Fluka-Chemika) in water and made up to 100.00 mL volume.

2.2 Thread based analytical device

Cotton thread was chosen to fabricate our devices receiving from Chom Thong factory, Chiang Mai, Thailand. A cotton line exhibits physical appearance of approximately 0.3 mm in diameter and a cotton line composes of fibers of 13±2 μm in diameter.

For thread-based device as shown in Figure 1, each cotton line (10 cm per line) was attached on plastic sheet using transparent tape. Then, SDS solutions, 0 to 5000 mg/L, were added to container in a volume of 300 μl.

To begin, cottons on plastic were dipped into container for 20 minutes. Different concentrations of SDS penetrated on thread with different distances. Then, mobile phone camera was used as a detector to take a picture and link the information to a program of distance's evaluation (ImageJ).

3. Results and discussion

It should be that the move of anionic surfactant along the thread microfluidic platform should be due to wetting properties, which would involve the balance of capillary force and surface tension [19, 20]. Thread as cellulose would nominate positive polarity [21] and that would influence the move of anionic surfactant with negative polarity.

Effect of the numbers of cotton fiber on a bunch of thread was studied. Different bunch sizes of the cotton thread consisting of 1,2,4 or 8 lines twisting together were tried .One end of each was put into a SDS solution (5,000 mg/L) .The distance of the SDS move was marked with a pen for each, before being photo taken. The results of triplicate experiments are represented in Figure 2.

It was found that the shorter distance was observed with the more numbers of lines twisting together.This could be due to

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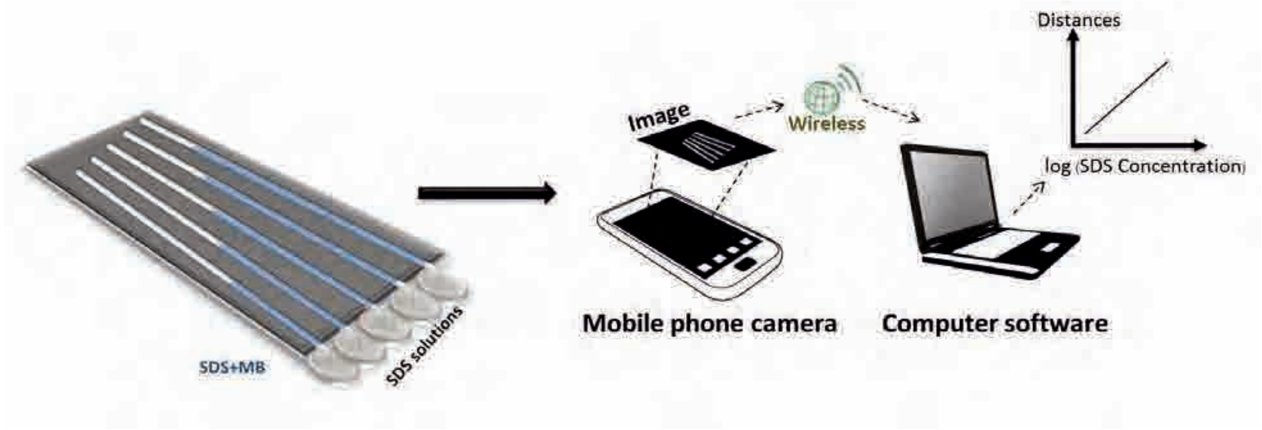

Figure 1: The proposed cotton thread based analytical device

the balance of the capillary force and surface tension in that platform. A 2 lines twisting thread was selected for further use.

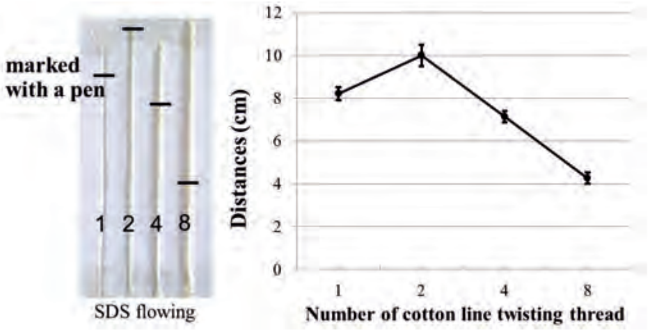

Figure 2: Effect of the numbers of cotton fiber [triplicate results]

Next, we studied the platform configuration as demonstrated in Figure 3. Three types were investigated including vertical (Figure 3A), horizontal without sheet (Figure 3B), and horizontal with sheet as shown in Figure 1. The results are represented in Figure 4. It was found that type C was appropriate for this work because the longer distance would be obtained. This could be due to the surface tension gaining from the supporting material.

The move of anionic surfactant along the thread platform is not easily observed, as without color development but marking the points with a pen before taking photograph would help.

To tackle this, after SDS solutions (0.1-100 mg/L) flowed along the thread for 20 minutes, it was immersed into MB (0.0934% w/v), blue color in the part of the anionic surfactant. By doing this, the photographs will allow the easy and convenient measurement the distance of the move of the anionic surfactant along the thread platform, which relates to the anionic surfactant concentration, as represented in Figure 5 and Table 1.

Table 1: Distances of the SDS moves on the thread

SDS concentration		Distances (pixel)				
mg/L	log value	Experiments				
		1	2	3	4	Average
0.1	-1	244	236	224	239	236±9
1	0	358	405	375	365	376±21
10	1	497	524	514	489	506±16
100	2	645	609	625	618	624±15

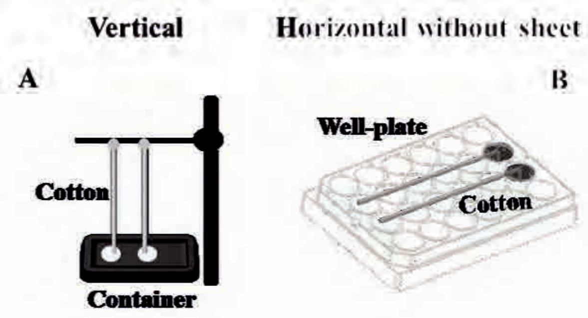

Figure 3: Effect of cotton platform geometry

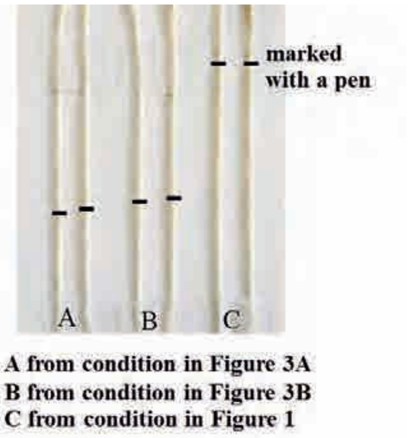

Figure 4: Thread resulted using the condition of Figure 3A, Figure 3B and Figure 1

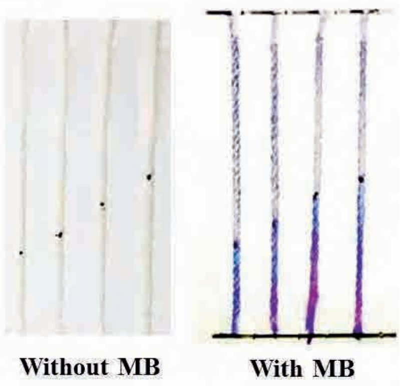

Figure 5: The move of SDS with MB immersion

The plot of log values of SDS concentrations against distances of the move exhibits straight line with an equation : y = 129x+ 371 ; r^2 = 0.999 where x being log(SDS concentration) and y being distance as shown in Figure 6.

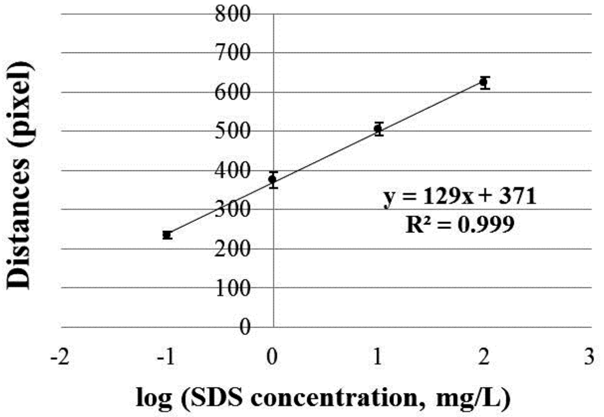

Figure 6: The calibration graph for SDS determination

It should be noted that although conventional way of the distance measurement could be made by putting a scale on sheet aside of the thread platform, using a mobile phone for taking photo of the thread platform would give benefit in being able to make use a software program such as ImageJ, to evaluate the distance. There are other benefits such as to keep records for filing and traceability purposes.

4. Conclusion

The work demonstrated a new concept in possibility of green analytical chemistry using cotton thread based analytical device for the assay of anionic surfactant without using organic solvent and with micro liter operation with the use of mobile phone. Further investigation for more sensitivity and application to real samples are in progress.

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References

[1] E. Jurado, M. F. Serrano, J. N. Olea, G. Luzon, and M. Lechuga,*Chemosphere*, **65**, 278 (2006).

[2] B. Wyrwas and A. Z. Grzeskowiak, *J. Surfact. Deterg.*, **17**, 191 (2014).

[3] B. Karlberg and S. Thelander, *Anal. Chim. Acta*, **98**, 1 (1978).

[4] C. WH, L. AWM, and L. J-Z, *Anal. Chim. Acta.*, **361**, 55 (1998).

[5] A. Cladera, M. Miro, J.M. Estela, and V. Cerda, *Anal. Chim. Acta*, **421**, 155 (2000).

[6] W. Praditwiengkum and K. Grudpan, *J. Flow Inject. Anal.*, **17**, 202 (2002).

[7] Standard Method for the Examination of Water and Waste Water, 17th ed., American Public Health Association, 1989, p. 59.

[8] R. Burakham, S. Lapanantnoppakhun, J. Jakmunee, and K. Grudpan, *Talanta,* **68**, 416 (2005).

[9] K. Grudpan, *Talanta,* **64**, 1084 (2004).

[10] M. Reches, K. Mirica, R. Dasgupta, M. Dickey, M. Butte, and G. M.Whitesides, *ACS Appl Mater. Interface,* **6**, 1722 (2010).

[11] D.R. Ballerini, X. Li, and W. Shen, *Biomicrofluidics*, **5**, 0141051 (2011).

[12] T. L. Owens, J. Leisen, H. W. Beckham, and V. Breedveld, *ACS Appl. Mater. Interfaces*, **3,** 3796 (2011).

[13] D. R. Ballerini, X. Li, and W. Shen, *Anal. Bioanal. Chem*, **399,** 1869 (2011).

[14] G. Zhou, X. Mao, and D. Juncker, *ACS Appl. Anal.Chem*, **84,** 7736 (2012).

[15] A. Nilghaz, D. R. Ballerini, X. Fang, and W. Shen, *Sens. Actuators, B*, **191**, 586 (2014).

[16] X. Mao, T. E. Du, Y. Wang, and L. Meng, *Biosens. Bioelectron*., **65**, 390 (2015).

[17] T. E. Du, Y. Wang, Y. Zhang, T. Zhang, and X. Mao, *Anal. Chem. Acta*, **861**, 69 (2015).

[18] K. Grudpan, S. D. Kolev, S. Lapanantnopakhun, I. D. McKelvie, and W. Wongwilai, *Talanta.*, **136**, 84 (2015).

[19] Y. Yuan, T. R. Lee, *Springer Ser. Surf. Sci.*, **51**, 3 (2013).

[20] G.Z. Zhou, R. Safaviah, X. Mao, and D. Juncker, *Biomed. Eng.,* **25** (2010).

[21] M. Clark, Handbook of textile and industrial dyeing, Woodhend Publishing, 2011, p. 322.

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