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Noodle based analytical devices for cost effective green chemical analysis

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ABSTRACT

Noodle based analytical devices are proposed for cost effective green chemical analysis. Two noodle based analytical platforms have been examined. Conditions for flow with laminar behaviors could be established. Detection may be via a webcam camera or a flatbed scanner. Acid-base reactions were chosen as a model study. The assays of acetic acid and sodium hydroxide were investigated. Apart from bromothymol blue, simple aqueous extract of butterfly pea flower was used as a natural reagent. Another model was the assay of copper (Cu^{2+}) which was based on the redox reaction of copper (Cu^{2+}) with iodide to produce tri-iodide forming brown/black product with starch which already exists in the noodle platform. Demonstration to apply the noodle platforms for real samples was made.

1. Introduction

Green analytical chemistry has been in awareness to reduce in sizes of operation including consumption of reagent, especially toxic ones but with appropriate analytical characteristics [1]. Various approaches and techniques have been considered for the purposes, such as flow injection analysis and its related techniques [2,3]. Down scaling chemical analysis for reducing the size of assay would reduce the amounts of substances. This could result in lower cost, shorter analysis time and less wastes. A number of such development has been in progress. Lab on chip (LOC) has been developed in various formats. In the early stage, glass/silica based materials were employed [4]. Fabrication of such LOCs engages complicated tasks. Cellulose based materials as analytical platforms including paper based and cotton/cloth based analytical devices have been reported [5,6]. Flow behaviors of those engage microfluidic characters.

Noodle is a common staple food in Asia. It is easily locally available. One type of noodle is made of rice which is a major annual crop available in the region. Regarding environmental aspects, cultivation for rice product would be greener than that of wood for paper. Rice is mainly composed of starch which is a kind of carbohydrate but different bonding from cellulose. The difference in their structure makes rice more easily decomposable than paper. It is then of interest to investigate rice noodle as a new analytical platform employing microfluidic behaviors.

In this study, fabrication of noodle based analytical devices has been explored. Chemical analysis based on microfluidic behavior was made using simple known reactions as model systems. This included acid-base neutralization reaction of acetic acid and sodium hydroxide for the acid and the base assays. Apart from bromothymol blue (BTB) indicator, simple aqueous extract of butterfly pea flower was used as a natural reagent. Another model is the assay of copper (Cu^{2+}). Redox reaction of copper (Cu^{2+}) with iodide to produce tri-iodide forms the product with starch in which was available in the noodle platform. The self-indicator property of the noodle platform provides additional advantage.

2. Experimental

2.1. chemicals and reagents

All chemicals used were of laboratory reagent grade. Bromothymol blue (BDH Prolabo, United Kingdom), Sodium hydroxide; NaOH (Univar, Australia), 99.7% Glacial acetic acid (RCI Labscan Limited, Thailand), Copper sulphate pentahydrate, $CuSO_4{\cdot}5H_2O$ (98% assay) (Fisher, United Kingdom) and Potassium iodide, KI (99% assay)(Ajax Finechem Pty Ltd, Australia) were used as received. Deionized (DI) water was used for preparing the solutions throughout.

Bromothymol blue (BTB) indicator solutions were prepared in DI water and 0.05 M NaOH.

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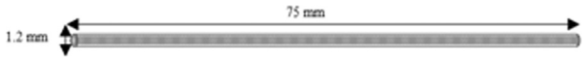

Fig. 1. A graphic illustration of the noodle platform I showing a glass capillary tube containing a dried noodle rod. (not to scale).

Crude extract of butterfly pea flower was prepared by soaking 2.0 g of dried flower in 100 ml DI water at 100 °C for an hour and then the solution was filtrated with filter paper (no.1, Whatman)

2.2. Fabrication of noodle platforms

A noodle platform I consists of a glass capillary tube containing a noodle rod (dried rice flour noodle, trade name of Wai Wai, usually used for cooking) (Fig. 1, see photo in ESI Fig. S1). Dried rod shaped noodle (diameter ca. 1 mm, length 75 mm) was inserted into a glass capillary tube (inner diameter 1.2 mm). When a solution was introduced on an end of the noodle platform, capillary action occurred in a small space between noodle surface and the glass wall causing the solution to move forward along the tube.

A noodle platform II was prepared by boiling a flat shaped noodle (dried rice flour noodle, trade name of also Wai Wai, usually used for cooking) (Fig. 2, see photo in ESI Fig. S2) in DI water at 100 °C for 3 min. Then it was strained and left to become semi-dried. The noodle will be retracted and lifted up to have edges at sides forming a channel with 3 mm width and 5 cm in length with volume ca. 30 µl on the noodle platform as illustrated in Fig. 2.

2.3. Two methods for introducing solution onto the noodle platforms

All analyte/reagent solutions were introduced on the noodle platform precisely using an automatic micropipette which is commonly available in most laboratory.

For the first one, a reagent was fixed on the noodle platform by immersing it completely into a reagent solution container. This method is suitable for pretreatment with a stable and long-life reagent as it could be stored as a pretreated dried noodle platform. An analyte solution was then dropped at one of the ends of the noodle platforms. For the other method, this would be suitable for an unstable reagent, the reagent solution was dropped onto one end of a noodle channel at the same time of dropping the analyte solution onto the other end. A multi-headed autopipette was used to synchronize the introduction of solutions onto two ends of the noodle platform.

2.4. Detection system

The reactions were followed by using a flatbed scanner (Canon LiDE200, Flatbed scanner, Vietnam) or a webcam camera (Oker T-45 webcam chat, Taiwan). Light condition was controlled by homemade light box. An in-house developed software [7] was used to control a device including record photos and color intensity (red (R), green (G), blue (B) and grayscale (I)). ImageJ software was also used for the purposes.

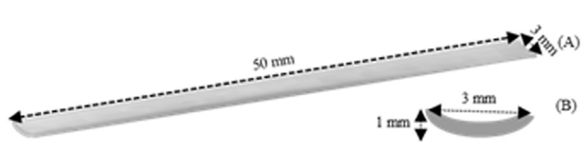

Fig. 2. A graphic illustration of the noodle platform II showing (A) top view and (B) cross section view. (not to scale).

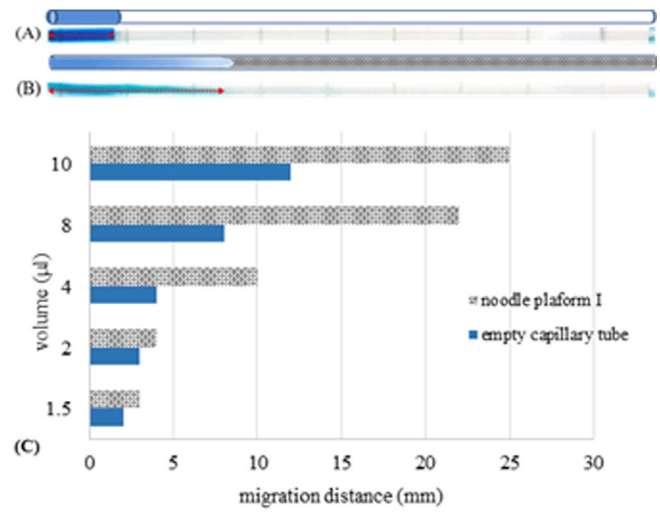

Fig. 3. A graphic illustration showing solution movement in (A) a bare capillary tube and (B) a noodle platform I (i.e. a capillary tube with noodle rod inside). (C) A bar chart showing migration distance in a bare capillary tube and a noodle platform I when increasing the solution volume.

3. Results and discussion

3.1. Flow phenomena in laminar pattern

As to make use of the noodle platforms for chemical analysis, flow phenomena in each type of the platforms were investigated.

3.1.1. In the noodle platform I

Flow phenomena on the noodle platform I were studied by adding an aliquot of aqueous dye solution (0.1%(w/v) bromothymol blue in 10 mM phosphate buffer solution) directly onto one end of the noodle rod. No diffusion of the solution on the bare noodle rod was observed. When the noodle rod was assembled into the glass capillary tube, it was found that the dye solution was able to diffuse into the space between the noodle surface and the glass wall; as a result of capillary force and surface tension, as illustrated in Fig. 3(A) and (B). It could be seen that under the condition set, laminar flow and controlled dispersion could be established. It should be noted that the volume of solution would affect the migration length as illustrated in Fig. 3(C).

3.1.2. In the noodle platform II

It was carried out by adding an aliquot of the dye solution onto one end of the noodle channel pretreated with a buffer solution (10 mM phosphate buffer, pH 6.0). Fig. 4 shows that the solution was able to diffuse toward the other end and a migration distance increased as a function of time until becoming constant.

From this study, the different flow phenomena in each noodle platform was suggested to be a result of individual characteristics of each noodle type. The movement of solution in both noodle-based analytical devices I and II were found to be corresponding with microfluidic behavior. This would be due to results of the interaction of

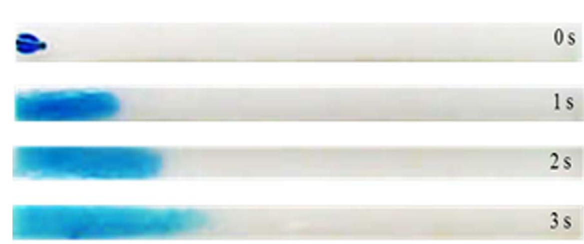

Fig. 4. A set of time series photos showing increasing migration distance after adding 10 µl dye solution on the noodle platform II.