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Designing Affordable Microchemistry Laboratory for Clinical Diagnosis, Education, and Field Work

[1,3]Akira Kikuchi, [2]Alaa Mohammed Mahmood, [3]Romaidi, [4]Vita Agustina, [4]Siti Nurkasanah, [4]Wira Eka Putra, [3]Evika Sandi Savitri, [3]Bayyinatul Muchtaromah and [5]Mutah Musa

[1]Institute of Environmental and Water Resource Management, Water Research Alliance, University Technology Malaysia
[2]Department of Chemistry, Faculty of Science, University Technology Malaysia
[3]Department of Biology, Faculty of Science and Technology, Maulana Malik Ibrahim the State Islamic University, Malang, Indonesia
[4]Department of Biology, Faculty of Mathematics and Natural Science, University of Brawijaya, Indonesia
[5]National Center for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation – Apata, Ibadan, Nigeria

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ABSTRACT

This article aims to investigate facile low-cost fabrication technique for microchemistry device. Affordable laboratory capacity for resource limited community was the targeted. The applied strategy was microfluidic paper base analytical devices (μ-PADs) assemblage on adhesive paper mount, which showed good performance for analytical capability and cost efficiency. The assembling process did not require any particular equipment or extensive technical training. Material cost was only 0.03 USD per a device. Finally, the offered prototype product was a simple plastic model , which consisted of μ-PADs elements, e.g. color code chart, double side adhesive tape, microfluidic channel, and blue print patterned paper mount in plastic zip lock bags enclosed in an envelop, which can be sent by mail service. The designing strategy was "to depend on users' resourcefulness" after extreme fixed costs had been eliminated.

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INTRODUCTION

Even the recent progress in the availability of potent drugs, there is still a limitation in access to clinical diagnosis, especially, in developing countries (Urdea, 2006). The WHO has set seven guidelines for the development of clinical diagnostics in resource-poor settings: i) Affordable, ii) Sensitive, iii) Specific, iv) User-friendly, v) Rapid and robust, vi) Equipment-free, and vii) Delivered to those who need it, corresponding to the acronym ''ASSURED'' (Urdea, 2006; Yatisen, 2013). Currently, micro-scale chemistry experimentation is the emerging break through approach to take on the challenge (Urdea, 2006; Yatisen, 2013; Nie, 2012). Application of such ASSURED devices are also expected in environmental monitoring (Graveline, 2010) and veterinary, food security, educational fields as well (Yatisen, 2013). It has been considered that the ASSURED device is one of the promised key technologies to improve public health, science education, and citizens' positive participation in environmental resource management (Urdea, 2006; Yatisen, 2013; Nie, 2012). It is still unknown the feature of the real ASSURED devices emerging close with communities in future world. Though, the development of a feasible platform technique for such device has high impact to global humanity and environmental conservation due to the fact that potential users could be most of the global population. This article aims to investigate facile low-cost fabrication technique of microchemistry device. Finally, the discussion will be concluded by a potential design of prototype products for affordable laboratory.

μ-PADs are currently considered as an ideal bio/chemical sensing platform for affordable laboratory due to its potential nature of ultra-low-cost (Yatisen, 2013; Martinez, 2010; Lisowski, 2013; Nery, 2013). The unique capability is well recognized by wide capability to combine many traditional and advance bio/chemical analysis techniques as paper base microfluidic devise with the property of low-cost, simplicity, and portability (Yatisen, 2013; Martinez, 2010; Lisowski, 2013; Nery, 2013). There are two types of techniques to fabricate the device. The first is hydrophobic wall creation by patterning hydrophobic materials, where wax printing (Ballerini, 2012) or UV curable ink printing (Citterio, 2011) seems the most

Corresponding Author: Akira Kikuchi, Institute of Environmental and Water Resource Management, Water Research Alliance, University Technology Malaysia
E-mail: kikuchiakira@hotmail.com

promising approach. The second utilizes air-solid phase boundary which is generally defined as cutting method (Yatisen, 2013; Martinez, 2010; Nery, 2013). However, these methods still require specially-modified printer, expensive high power UV lamp, computer controlled x-y knife plotter, laser, and CO_2 laser cutter (Yatisen, 2013; Martinez, 2010; Nery, 2013). Thus, there has been a gap in the development of new fabrication techniques that are special equipment free, inexpensive, and widely applicable without technical personnel, also possible to apply at small laboratories, schools, and by various actors in the private sector even in remote regions.

Methodology:

We utilized our trial technique to fabricate µ-PADs by an idea of µ-PADs on adhesive paper mount. Fig. 1 is a schematic depiction of the skill for glucose sensing µ-PAD. ADVANTECH No. 51A filter paper was cut by cutter and used for single channel sampler (1x20mm), and bridging microfluidic channel (1x10mm). ADVANTECH No. 526 filter paper was punched out by office-use single puncher, and 8 µL glucose sensing ink [4] was added by micro pipette to make glucose sensing patch. ADVANTECH No. 51A filter paper was punched out in the same way, and added 3 µL of 1% potato starch solution to make starch patch for signal amplification purpose. These were dried at room temperature. Paper mount was designed by MS Power point 2003. On the paper mount, all the information for blue print of µ-PAD, and experimental conditions were printed by ink-jet printer (Fig. 1b). Conventional double sided adhesive tape was used to make adhesive paper mount. Darkness, which is inverse relative luminosity, was analyzed by ADOBE Photo shop 7.

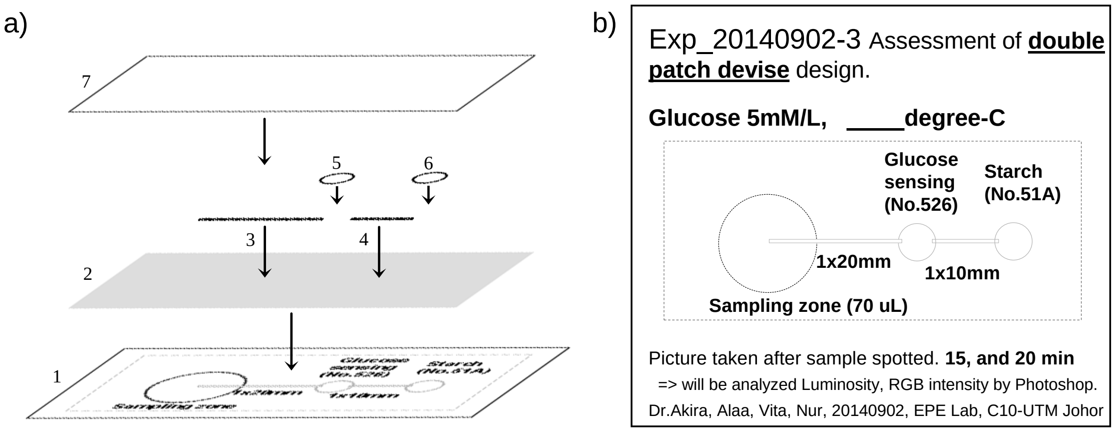

Fig. 1: An example of ultra-low-cost bio/chemical sensing device. a) Fabrication techniques of µ-PADs on adhesive paper mount. 1: Paper with patterned blue print, 2: double side adhesive tape, 3: single channel sampler, 4: bridging microfluidic channel, 5: glucose sensing patch, 6: starch patch, 7: release paper originate from double side adhesive tape. b) Example of adhesive paper mount.

RESULTS AND DISCUSSIONS

µ-PAD was assembled on adhesive paper mount by following the procedure described (Fig. 1a). Double sided adhesive tape was stacked on paper mount, and release paper was removed and kept at clean space. Microfluidic channels were settled by tweezers on adhesive paper mount along the blue print. Subsequently, glucose sensing patch and starch patch were settled by tweezers, respectively. Then, release paper was laminated from top, and the assembled device was pressed by finger from the surface for good wicking of µ-PAD elements with each other. The assembling process was easy to perform and not time consuming.

The lamination was removed just before the experiment. Then, small volume of 5mM/L glucose standard solution (70 µL) was dropped at sampling zone. The sample moved to glucose sensing patch by lateral capillary flow, where glucose was converted into iodide at glucose sensing patch (5min). The iodide gradually transferred to starch patch by continuous lateral capillary flow, and dark gray colour was formulated by iodo-starch reaction at starch patch (10min). Significant colour formulated at starch patch after 20 min (Fig. 2). Calibration curve was plotted describing the relationship between the relative darkness of the colour developed at the starch patch and glucose concentration (Fig. 2). There was slightly visible difference in colouring for 0.1-1 mM/L glucose concentration which is concentration level of the analyte in normal urine sample (Fig. 2). The colouring was visibly significant from around 5 mM/L which is equivalent to concentration level of glucose in normal blood sample (Fig. 2). These results indicated the potential applicability of µ-PADs on adhesive paper mount, which requires no special skill if parts of µ-PADs are prepared. The material cost to make one µ-PAD devise was extremely low (0.03 USD/device), which indicates that the actual price of such µ-PADs will be controlled by personnel expense and distribution cost.

The proposed strategy offered a basic advantage of µ-PAD, as the device can be fabricated easily, and the assembling process does not require any particular equipment or extensive training. According to our method, parts of µ-PADs are easy-to-make by simple equipment that are available at small laboratory (at least analytical balance, and micro pipette, clean glassware), and other tools that are possible to prepare in down town or already are available in an office. On this basis, wide extension for analytical functionality could be the novel potential of this trial method. Accordingly, we arrived at a critical point where through common-opportunity that was feasible to prepare functional parts of µ-PADs, such as diverse menu of colouring patch for potential analytes, micro fluidic channel, separation strip, microfluidic channel switch, filter, mixing timing controller, and etc. In addition, it is highly predicted advanced bio-sensing elements will be developed by inkjet-printed paper fluidic immuno-chemical sensing strip (Abe, 2010), which will be applied to the µ-PADs on adhesive paper mount.

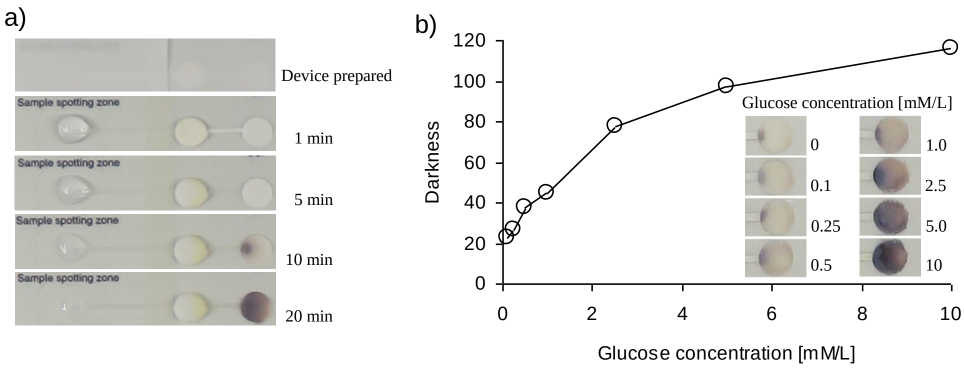

Fig. 2: Example of analytical performance of glucose sensing µ-PAD on adhesive paper mount, a) Testing by 5mM/L glucose standard solution. b) The calibration curve describing the relationship between the relative darkness of the colour developed at the starch patch and glucose concentration at 20 min after the sample was dosed.

In furtherance of the pursuit of this article, we suggest a prototype product of an affordable laboratory as µ-PADs on adhesive paper mount. The design is simple like plastic model for childhood, which is consists of µ-PADs elements, e.g. color code chart, double side adhesive tape, micro fluidic channel, and blue print patterned paper mount in plastic zip lock bags that enclosed in an envelop, which can be sent by courier service anywhere around the globe. Simple tweezers might be included with it. Historically, improved analytical devices have developed increase in special skill and fixed cost in manufacturing. The inevitable demand for affordable laboratory services is tending towards ultra-low-cost (Yatisen, 2013; Nie, 2012). Consequently, designing strategy of affordable laboratory has become inclined "to depend on users' resourcefulness" after extreme fixed costs are eliminated. This design is based on a biological analogy from life form of virus which is extremely outsourced with host cell functions.

Summary:

An idea of "µ-PADs assemblage on adhesive paper mount" showed good performance for analytical capability, facile handling, and cost efficiency. The assembling process did not require any particular equipment and extensive training, while the material cost was only 0.03 USD per device. The suggested strategy for the prototype product was "to depend on users' resourcefulness". The offered design was simple, which consisted of µ-PADs elements, e.g. color code chart, double side adhesive tape, microfluidic channel and blue print patterned paper mount in plastic zip lock bags that enclosed in an envelop, which can be sent by courier service. Users or local suppliers can fabricate µ-PADs by tweezers for their demands.

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