ULTRA LOW COST BLOOD DIAGNOSTIC CHIP FOR POINT-OF-CARE CLINICAL DETECTION

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ABSTRACT

The current requirement for expensive laboratory equipment and highly trained personnel highlight the critical need for simple, low cost technology capable of point-of-care (POC) clinical detection, especially in resource-limited regions. The primary goal of this work is to develop an innovative, ultra-low cost, plastic-based blood diagnostic platform for POC detection that require small volumes ($< 3 \mu\text{L}$) of whole blood. The novelty of our approach lies in the finger-powered asymmetric capillary force driven by the spray-coated superhydrophilic plastic plate that is integrated with adhesive tape. We simply quantified the biosensing capability of the blood diagnostic chip using a finger-powered, capillary-driven colorimetric assay.

INTRODUCTION

Blood tests are integral in global health applications (such as infectious diseases) due to the massive amount of critical information it contains that relates to how the whole body is functioning [1]. The need for only a small volume of blood in blood tests is particularly useful for POC detection from pediatric/neonatal patients in resource-limited and geographically isolated regions, including developing countries. Typical methods and most of the reported lab-on-a-chip (LOC) devices [2, 3] have several restrictions that include the need for an external power source, bulkiness, expense, and on-chip platform that lack sufficient integration. Therefore, it is very desirable to develop a simple, low cost technology for POC detection.

Figure 1: Schematic overview of the fabricated ultra-low cost blood diagnostic chip for point-of-care clinical detection.

In contrast to the expensive and labor intensive diagnostic approaches currently being used, our work is unconventional. Anyone can easily fabricate the plastic-based molecular diagnostic chip utilizing just four items: a coated polyethylene terephthalate (PET) plastic plate, regular adhesive tape, tweezers, and scissors (Figure 1). Utilizing a coated plastic plate and a straightforward fabrication procedure, we developed a simple, yet ultra-low cost blood diagnostic chip for the POC detection.

Figure 2: (A) Generation of asymmetric capillary force for blood plasma separation using a layer-by-layer nanoassembly spraying method; (B) difference of the static contact angle between hydrophobic adhesive tape and superhydrophilic PET.

WORKING PRINCIPLE AND RESULTS

At the center of this technology is a spray-coated superhydrophilic [4] PET plastic plate, shown in Figure 2. PET plates are designed for lateral transportation of whole blood by capillary pumping, asymmetric capillary-based blood plasma separation [5], and capillary-driven lateral flow colorimetric assay [6]. Assembled surface-modified PET plates, with adhesive tape, facilitate controlled blood plasma separation within seconds by finger-powered asymmetric capillary force (Figure 2A). The notable difference between the two selected surfaces for asymmetric capillary force is highlighted in Figure 2B.

The scientific principle underlying this proposed concept relates to the finger-powered, capillary-driven lateral flow colorimetric assay on the spray-modified nanoporous PET surface

(Figure 3). The tetrabromophenol blue (TBPB) solution shown is simply injected onto the nanoporous surface. Once the reaction begins, the phenol in TBPB deprotonates, and the color of the dye shifts to blue which indicates the presence of a spiked protein, bovine serum albumin (BSA), in the separated blood plasma. The coated nanoporous PET surface offers improved binding capabilities and enhanced transduction due to the high surface-to-volume ratio.

The intensity of the color change was quantified by a calibration curve in terms of the protein concentrations (Figure 4B). The regression equation is: $Intensity = 6.6112\ln(x) + 62.789$ ($R^2 = 0.9998$), where x is the concentration of protein (in mg/mL). The assay was calibrated with blood plasma samples separated in a device with known protein concentrations. The limit of detection was $25\mu\text{g/mL}$, which is better compared to typical methods as well as paper-based microfluidic device [7, 8].

Figure 3: Finger-powered, capillary-driven colorimetric assay in the blood diagnostic chip. (A) injection of chemicals onto the surface; (B) loading whole blood; (C) blood plasma separation; (D) colorimetric assay.

CONCLUSION

We have developed a novel, ultra-low cost, plastic-based POC blood diagnostic chip, and have further demonstrated its sensing capability using a finger-powered, capillary-driven colorimetric assay. This plastic-based, sample-to-answer, blood diagnostic chip can be mass-produced at low cost and is readily disposable by incineration. By utilizing minute quantities of whole blood and

reagents, the developed diagnostic chip also offers great potential for reducing costs while also facilitating rapid turnaround times, compared with conventional testing. Successful implementation of this device will significantly improve the timely and effective POC detection and management of patients, especially pediatric/neonatal patients in resource-limited and geographically isolated countries.

Figure 4: Procedure for quantification of protein concentration in human whole blood samples using the ultra-low cost blood diagnostic chip. The limit of detection was $25\mu\text{g/mL}$.

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