A CENTRIFUGAL MICROFLUIDIC PLATFORM - A COMPARISON

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Abstract

The fluidic platform introduced here is a multi-purpose micro analytical laboratory on a compact disc (CD) [1,2]. This system is based on the centrifugal force, in which fluidic flow can be controlled by the spinning rate of the CD and thus a whole range of fluidic functions including valving, mixing, metering, splitting, and separation can be implemented. Furthermore, optical detection such as absorption and fluorescence can be incorporated into the CD control unit to obtain signals from pre-specified positions on the disc. In this paper we present data on a two-point calibration system built on the CD platform and we compared this microfluidic platform with alternative fluidic systems.

Keywords: microfluidics, centrifuge, photolithography, SU-8

1. Introduction

The LabCD platform technology we are developing features fluidic components micromachined into a plastic CD. In the manufacture, we rely on traditional mechanical machining and on lithography based techniques. The centrifugal force due to the rotation of the CD provides the pumping force for the release and flow of reagents and analytes. No external pumps and valves are needed to control the fluids. We used computer numerical control (CNC) milling to mechanically manufacture the CD platform. Although CNC machining may not achieve satisfactory absolute tolerance, its accessibility and rapid prototyping capability enable us to conduct various investigations concerning microfluidic dynamics faster. For smaller fluidic features (<80 μm) and mass production, we are making the CD with a combination of photolithography and replication tools. In this approach, thick layers of SU-8 (SU-8-100, MicroChem, Inc.) are spin-coated on a metal covered plastic CD, followed by photolithography to pattern the microfluidic structures. After development, nickel is electroplated to make a metal-insert mold which can be used for hot embossing or injection molding.

Most miniaturized medical diagnostic systems that are on the market today feature a 1-point calibration only [3]. To alleviate some of the shortcomings of such analytical systems, we designed 2-point calibration system on the CD platform (Figure 1). In this system, the liquid flows in the order of calibrant 1, wash1, calibrant 2, wash 2, and sample to the optrode chamber by increasing the rotation speed. The same optrode chamber is used for measuring calibrants and sample to eliminate artificial system errors common with devices using separate chambers for measuring sample and calibrants.

For optical detection purposes, chromoionophore is incorporated into small chambers close to the rim of the CD. To demonstrate the functionality of the 2-point calibration system, we deposited ion selective membrane in the optrode chamber by a micro-delivery set-up (Nano-

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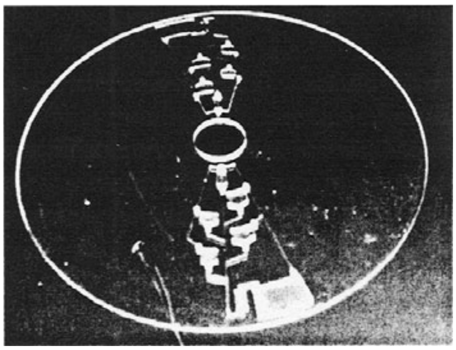
plotter, GeSiM). The membrane is composed of Poly(vinyl chloride) (PVC), ionophore, dioctyl sebacate (plasticizer), and chromoionophore for detection at 640 nm wavelength. In order to identify the proper polymeric material with the lowest protein adsorption and minimal optical interference with the optical measurement, the protein adsorption characteristics and optical absorption properties of seven candidate polymers for the CD platform were evaluated.



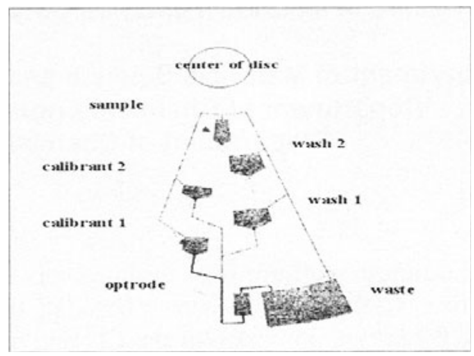


Figure 1. (a) The "2-point Calibration" system.
(b) Functional diagram of a single 2-point calibration unit.

2. Experimental

2.1. Fluid Propulsion

In order to sequentially valve fluids through a monotonic increase of rotational rate, we want to design a structure with progressively higher "burst" frequencies. The burst frequency is the frequency at which fluids are released from their reservoirs.

In our LabCD platform, the centrifugal force provides the pumping force, while the capillary force tends to inhibit flow. Therefore, a rpm-dependent "valve" can be formed controlling the release and flow of fluids. The centrifugal and capillary forces can be described as follows:

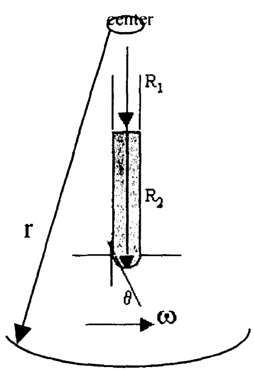


Figure 2. Schematic illustration of fluid propulsion in Microfluidics.

The pumping force (dP_c) due to centrifugal force is given by:

$$\frac{dP_c}{dr} = \rho\omega^2 r \qquad (1)$$

T he capillary force (ΔP_S) due to surface tension is given by:

$$\Delta P_s = \frac{\gamma\cos\theta \cdot C}{A} \qquad (2)$$

In these equations, ρ is the density of the liquid, ω is the angular velocity of the CD platform, r is the distance between