

Fabric as a Low-cost Microfluidics Platform for Medical Diagnostics

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Microfluidic diagnostic tests, such as pregnancy and HIV dipsticks, can be operated on small sample volumes, consume less resources and are a viable alternative to bench-top assays in resource-deprived medical laboratories [1]. However, such paper and polymer-based microfluidic systems are typically manufactured by serial processes which are low-throughput and expensive, making them unaffordable to most rural medical centers in developing countries. In my prior work at Achira Labs, Bangalore, India, we proposed textile-weaving for low cost and scalable fabrication of microfluidic diagnostic tests [2]. Weaving allows the serial processes of patterning and reagent deposition to be combined into a single fabrication step. Pre-coated or functionalized yarns consisting of biochemical reagents and electrical components are introduced into the fabric during the weaving process, with multiple devices being patterned simultaneously across the width of the loom. An immunodiagnostic assay for pregnancy was demonstrated in a silk fabric device, with an estimated throughput of over 10,000 devices per day per weaver at less than a dollar per test.

In order to do so, we needed to establish the feasibility of fabric as a platform for fluid manipulations. The ability to direct liquid flow along a predetermined path was demonstrated by patterning hydrophilic, wetting yarns into a relatively hydrophobic background made from metalized yarn (Fig. 1).

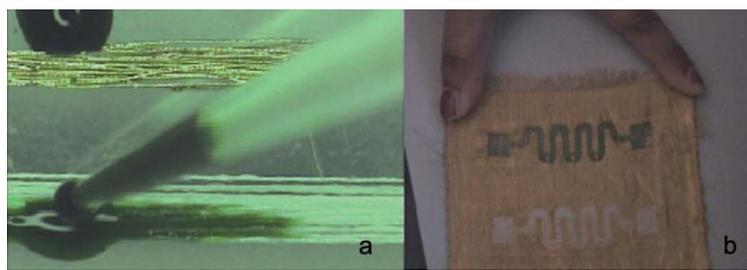


Fig1 (Ref 2) (a) Brass coated yarn (upper) rejects a drop of aqueous dye deposited on it, while degummed, surfactant treated silk yarn (lower) allows the fluid to flow along its length. (b) A fabric chip showing selective wetting. Aqueous green dye solution deposited at one end flowed only along the hydrophilic yarns. An unused chip (white) is shown for contrast.

Further, by relating fabric to a bundle of capillary tubes which obey the Washburn Equation for capillary flows ($\text{Length}^2 \sim \text{Pore Diameter} * \text{Time}$), we see that an *effective* pore size can be used to influence flow velocity. Velocity could therefore be set by changing pore size using both macroscopic, weaving-dependent parameters and further, microscopic or yarn parameters. The smallest pores are in the intra-yarn spaces, often lesser than 25 μm in size, indicating that microfluidic length scales could be achieved for highly sensitive applications.

Additionally, passive ‘valves’ could be woven in order to slow down sample flow through regions where time-sensitive reactions are desired. In order to demonstrate this ability, fabrics were given a pore-diameter gradient along the flow path. Velocity profiles (with respect to flow length) could be predicted using the Washburn Equation. Gradient fabrics were designed to generate flat and stepped-down velocity profiles as opposed to the typical swooping trend seen in a homogeneous fabric. The assay demonstrated in this fabric was twice as sensitive as the commercially available pregnancy test.

A new electrophoresis function for fabric is now being developed in the Murthy Lab, with Platinum wire electrodes woven into a polyester channel. Prototypes were made on a handloom located in Achira Labs, Bangalore, India. The results support the long term goal of my project, which is to create a low cost, fabric platform for separating the protein components of a biological sample with applications in diagnosing liver, kidney and endocrine disorders.

References:

1. Paul Yager, Gonzalo J. Domingo, and John Gerdes, Annual Review of Biomedical Engineering, 2008
2. Paridhi Bhandari & Tanya Narahari, Dhananjaya Dendukuri, Lab On a Chip, 2011