Lab-on-a-Chip Application: Microfab-less Microfluidics for a Portable Hybrid Microchip-Capillary Electrophoresis Device

Matthew T. Gordon and Carlos D. Garcia
University of Texas at San Antonio, San Antonio, TX

Microfluidic devices, with their potential for portability and rapid analysis times, can bring cost-effective flexibility to modern analytical chemistry applications. However, the design and fabrication of microchips can involve trade-offs between cost, flexibility of configuration, and ideal surface properties or performance. To circumvent these drawbacks, we have developed a hybrid platform consisting of simple microfabricated reservoirs connected to standard capillary tubing for electrophoretic separation and in-channel detection. The connections for this hybrid device are assembled using a reusable, conventionally machined CapTite™ Ultem® cross interconnect and CapTite™ PEEK™ capillary fittings. The Ultem® central interconnect, silicone reservoirs, and conductivity detector can all be mounted to a portable breadboard for stability. The use of standard capillary tubing with a conventionally machined cross supports versatile system configurations and simultaneously eliminates the cost in money and time that is associated with customized microfabrication. Here, we demonstrate the capability of the inherently flexible and cost-effective hybrid microchip-capillary electrophoresis device with the optimization of the separation of inorganic cations.

INTRODUCTION

The development of microfluidic devices has changed the face of analytical chemistry and medical diagnostics. These relatively inexpensive, portable devices have reduced analysis times and contributed to analyses of various targets while competing with traditional benchtop instruments. While there have been advancements in the materials and technologies used for microfabrication, the ideal combination of a high-performing analytical device with low production costs has not yet been attained. Additionally, microchip separation devices are inherently non-reconfigurable and can limit the in-channel detection options. To avoid these drawbacks, we investigated the feasibility of using reusable, conventionally machined LabSmith CapTite™ components to create a hybrid microfluidic platform for electrophoretic separations featuring standard capillary tubing coupled to simple, minimally fabricated reservoirs.

Microchip-capillary electrophoresis hybrid devices retain the portability of a chip-only platform and bring additional flexibility in separation and detection options. The innovative feature of using LabSmith CapTite™ components for this plug-and-play hybrid system is modularity, allowing for assembly or reconfiguration of the device in a matter of minutes. The capillary tubing can be swapped out to adjust for specific conditions or material adjustments and the hybrid platform can accommodate different lengths of tubing to optimize separation efficiency. Thus, this microchip-capillary electrophoresis hybrid device delivers simple, low-cost assembly and re-usability without sacrificing high performance capabilities. Furthermore, in place of costly, custom-designed microfabricated devices, we have utilized the LabSmith CapTite™ fluid-routing components and breadboard to link the microchip and capillary pieces of the hybrid system (Figure 1).

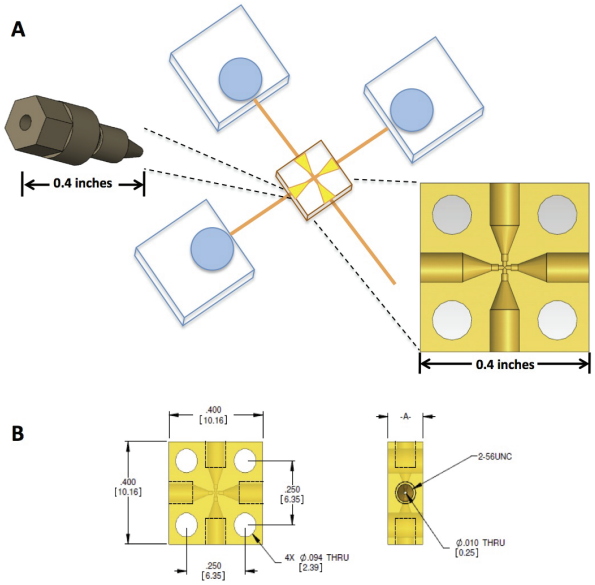

Figure 1. Schematic of the hybrid microchip-capillary electrophoresis system. (A) Microchip reservoirs (in blue) connect to standard capillary tubing (in orange) to form a hybrid microfluidic system. Buffer and sample streams are routed through the LabSmith Ultem central interconnect cross (in brown). Inset at left depicts the reusable CapTite fitting that secures the capillary to the Ultem cross. Inset at right portrays central interconnect cross. (B) Dimensioned drawing of Ultem capillary-chip interconnect components, available from LabSmith.

LabSmith
TOOLS FOR SCIENCE

6111 Southfront Rd. Suite E, Livermore, CA 94551
Phone (925) 292-5161 | Fax (925) 454-9487
www.labsmith.com | info@labsmith.com

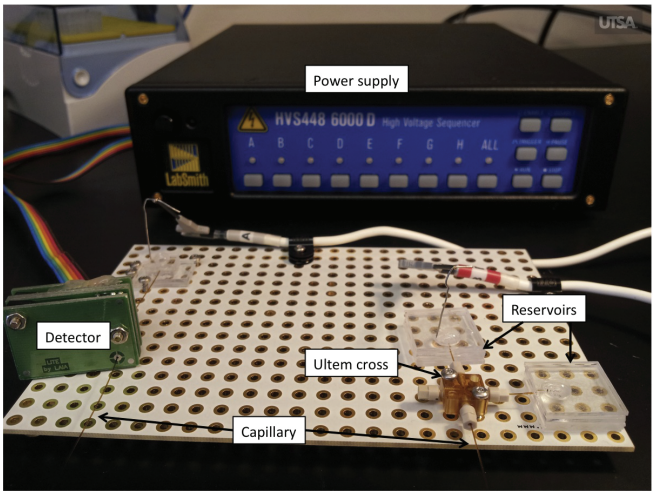

Figure 2. Setup of microchip and LabSmith CapTite™ components on the LabSmith uProcess™ breadboard for sample analysis.

EXPERIMENTAL AND RESULTS

In the hybrid system described here, capillary tubing connects the microfuidic sample and buffer reservoirs to the LabSmith CapTite™ cross (Ultem®) central interconnect (Figures 1 and 2). This multiport fitting, with only 38 nL dead volume and 250 um through hole, enables the routing of the sample and buffer on to the separation channel via voltage control, as delivered by the programmable LabSmith High Voltage Sequencer. The capillary tubing is secured to the CapTite™ cross using CapTite™ reusable PEEK™ fittings for 360 um o.d. tubing (Figure 1). The removable, reusable fittings facilitate the plug-and-play exchange of capillary tubing as needed for various applications or optimization of separations. Additionally, the use of capillary tubing enables use of this platform with a number of inline detection methods, such as C4D demonstrated below (Figure 2 and 3). To ensure stability of the portable device, the various fluid routing components of the hybrid system can be attached to the LabSmith breadboard for physical stability.

Table 1. Cost comparison of hybrid and standard microfluidic platform assembly.

LabSmith components	Custom Microfabrication
<$100 (Cross + 4 Fittings)	$150 – 200 per chip with fluid reservoirs and fittings

SUMMARY

With this microchip-capillary electrophoresis hybrid device, we have achieved baseline separation of inorganic cations in soil samples from the Atacama Desert (Segato et al.; Figure 3). The flexibility and versatility of the system allowed us to test multiple buffer solutions (with and without additives) and adjust capillary lengths to optimize our targeted separation. Furthermore, reproducible sample loading was achieved with the LabSmith HVS448-6000D programmable eight channel high voltage sequencer through the CapTite™ cross interconnect and one-piece fittings for tubing connections. Taken together, these studies present a simple, inexpensive platform to perform rapid, reproducible sample analysis using an easily assembled stable hybrid system (Table 1). The interchangeable and customizable aspects of the microchip-capillary electrophoresis hybrid device make this convenient, cost-effective platform viable for current and future microfluidic applications.

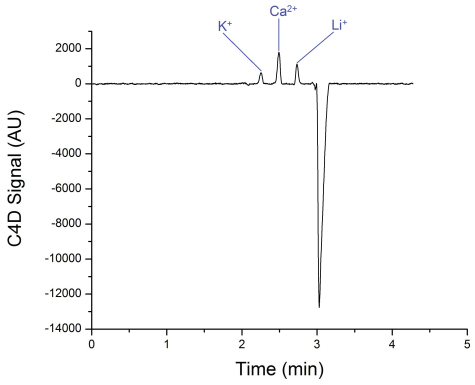

Figure 3. Baseline corrected separation of inorganic cations achieved using the hybrid microchip-capillary electrophoresis device driven by the LabSmith programmable High Voltage Sequencer. Separation conditions: **equimolar MES and HIS buffer (pH = 6.), 3 mmol L^{-1} 18-crown-6, E_{SEP} = 10 kV, capillary length = 60 cm, effective length = 56 cm, 5 s hydrodynamic injection.**

REFERENCES

Segato, T. et al. *Analytical Methods*, 2013, 5, 1652-1657.

LabSmith
TOOLS FOR SCIENCE

6111 Southfront Rd. Suite E, Livermore, CA 94551
Phone (925) 292-5161 | Fax (925) 454-9487
www.labsmith.com | info@labsmith.com