

DROPLET EXTRACTION FROM A LIQUID COLUMN FOR ON-CHIP MICROFLUIDICS

CROSS-REFERENCE TO PRIOR APPLICATIONS

[0001] The present application is the non-provisional version of U.S. Provisional Patent Application 60/728,985, filed on 22 Oct. 2005, and claims the benefit and priority of that application.

U.S. GOVERNMENT SUPPORT

[0002] This experiments leading to the instant invention were supported by a Dept of Homeland Security Advanced Research Projects Agency (HSARPA) SBIR Phase I grant, number NBCHC050123.

BACKGROUND OF THE INVENTION

[0003] 1. Area of the Art

[0004] The present invention concerns the art of microfluidics—namely the transport and processing of fluid samples on a micro-scale.

[0005] 2. Description of the Background Art

[0006] This invention addresses the problem of extracting sample droplets from liquid columns by means of surface phenomena, particularly by means of electrowetting, to enable multi-staged separation and analysis functions external to the original microfluidic circuit. Digital Microfluidics (see, “Creating, Transporting, Cutting, and Merging Liquid Droplets by Electrowetting-Based Actuation for Digital Microfluidic Circuits” Sung Kwon Cho, Hyejin Moon, and Chang-Jin Kim, *Journal of Microelectromechanical Systems*, V. 12, NO. 1, February 2003, pp. 70-80; and M. G. Pollack, R. B. Fair, and A. D. Shenderov, “Electrowetting-based actuation of liquid droplets for microfluidic applications,” *Appl. Phys. Lett.*, vol. 77, no. 11, pp. 1725-1726, 2000) is used as an example technology for demonstrating on chip droplet extraction. One of ordinary skill in the art will recognize that the present invention is applicable to a number of fluidic technologies where a fluid is transported in a channel, or column, and it is desired to remove a sample of the fluid without disturbing the overall transport. “Column” includes the usual devices of fluidic conveyance such as a channel, pipe, or capillary (e.g., a tube where physical walls constrain the fluid) as well as any configuration whereby a fluid is made to flow in a directed stream (e.g., a surface where surface properties constrain a flowing film of fluid to a portion of that surface). The liquid column can be formed by any arrangement that bounds or constrains the liquid flow in a particular direction or pathway, such as filling a liquid in a channel (e.g., physical walls constraining the fluid) or by applying non-uniform surface properties and effects to create a directional affinity for the liquid column (e.g. no physical walls)

[0007] In many cases the fluid column is designed not just to transport fluid but to separate and concentrate solute molecules or particles within the fluid. Many fluidic analysis systems and sensor chips (e.g., those useful in chem-bio, that is, chemistry and biology applications) utilize continuous liquid columns to transport as well as to separate and analyze fluidic samples. For example, microfluidic sensor chips often rely on walled liquid columns (microchannels) to transport and facilitate separation of a sample fluid into concentrated bands or zones of solute molecules or suspended particles by means of capillary electrophoresis (CE), Dielectrophoretic separation (DEP) and other separation techniques. Evalua-

tion of the concentrated bands resulting is typically conducted within (or at the end of) the liquid column by using a variety of optical, electrical or chemical analytical systems. To reduce the probability of error, it is desirable to evaluate the separated band with secondary separation and analytic devices. However, these secondary instruments are often not co-located with or in close proximity to the primary analytical device; rather they may be located downstream or external to the channel-structure and thus require the transport or transfer of the concentrated band from the primary analytical device to such secondary locations. The subsequent transport of the band to these secondary evaluation stations is difficult to achieve without disturbing the column of fluid in the primary channel thereby incurring unwanted diffusion or pressure-driven dispersion of the concentrated molecules or particles. Thus, in order to integrate or operate with multi-staged separation and analysis stations, it is essential to precisely excise discrete portions of the primary fluid column and preserve the concentrated bands during transport between analysis stations.

SUMMARY OF THE INVENTION

[0008] An inventive microfluidic device and method use a refill droplet to facilitate the extraction of a droplet from a channel or separation column in a microfluidic apparatus. There are many instances where it is advantageous to extract a portion of a fluid stream from a microfluidic channel or column. Such extraction allows a discrete band of separated particles or solute molecules to be excised from a fluid stream and processed and analyzed separately. The channel or separation column may be bounded by physical walls or it may exist on the surface of a fluidic device with its boundaries defined by differences in surface properties of the surface. An extraction point is located along the length of the column or channel. If the column or channel is enclosed by physical walls, the extraction point includes openings through the wall.

[0009] At the extraction point means are provided on one side of the column or channel to extract a segment of fluid from the channel or column. This is accomplished by providing an EWOD surface or other microfluidic technology for driving droplets adjacent the extraction point. Generally, the extraction point also includes an opening in the channel or column wall opposite the extraction means. This opening is equipped with an EWOD surface or other means to transport a refill droplet to the opening opposite the extraction means. When the extraction means attempts to pull a volume of fluid from the column or channel, the cohesive nature of water molecules resists this force and exerts an opposite “pull back” force. If the droplet is nevertheless extracted, the other bands of separated particles or molecules within the column or channel become mixed or distorted. Further, part or all of the contents of the channel or column may follow the extracted droplet effectively draining a portion of the microfluidic system. The refill droplet obviates this problem by neutralizing the “pull back” force and stabilizing the fluid stream within the column or channel. As the extraction means pulls the droplet out one side of the column or channel, the refill droplet is moved into the channel or column to occupy the area previously occupied by the extracted droplet. This prevents distortion or mixing of the bands of particles or mol-