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Laplace Pressure on Microfluidic Chips

Developing a microfluidic device presents many issues that are not prevalent in the macro world. Unique expertise is required to create manufacturable products that will be a commercial success. This *Tech Brief* describes one common challenge in microfluidics and how it's addressed.

There are many advantages to be reaped by moving chemical analysis from conventional millimetre-sized fluidics to the ca. 20 μm channel sizes found in microfluidic chips. Faster chemical and thermal diffusion, faster separations with higher resolution, lower sample consumption, integrated operations (injection, pre-column reaction, separation, post-column reaction and detection all occurring on the same chip) and portability are all advantages that have been realized in research devices as well as a few products. That said, there are also a number of inherent challenges that arise from making this leap. Effective integration of different sample manipulation stages, detection of the very small volumes of analytes that are resolved on the chip and connection to the milli- or microlitre-sized samples of the real world are all non-trivial issues to be dealt with. We will address the effects of microlitre-sized samples and Laplace pressure on microfluidic separations.

Laplace pressure arises from the surface tension of a liquid, for example at its interface with a gas in a solid container. The pressure exists across the curved surface of the meniscus and varies inversely with the radius of curvature. Laplace pressure is responsible for water being drawn into a wick or capillary made of a hydrophilic (or "water-loving") material such as glass; for water rising in a capillary, the pressure is lower below the meniscus (in the water).

When performing a free-zone electrophoretic analysis on a microfluidic chip, the chip is first filled with aqueous solution by capillary action, but when the samples and reagents are pipetted into wells on the chip, Laplace pressure also acts by virtue of the menisci in those wells. The wells are typically small, a few millimetres in diameter, so the surface of the liquid sample will have a small radius curve to its meniscus, depending on the nature of the reagents, chip materials used and their surface treatment.

We'll use an experimental example to illustrate. A researcher starts with equal meniscus levels and curvatures at all reservoirs (of identical size) and, over the course of several experiments, drives liquid intentionally along the network of channels with a pump or power supply to effect the analyses. There will also be 'unintentional' liquid flows or factors affecting flow, such as evaporation, buffer depletion and resultant changes in electroosmotic flow (EOF), siphoning, Joule heating and Laplace pressure. For simplicity, we will ignore all other unintentional contributors to flow and only consider Laplace pressure in this context. As liquid is intentionally driven from one well to another, each well's meniscus, anchored at the

top of the well, changes shape: the meniscus deepens in the depleted well (decreased radius, increased pressure), and becomes more shallow in the receiving well (increased radius, decreased pressure). As a result, liquid will flow under Laplace pressure against the intentional flow to the depleted well (from high to low pressure), quite independent of siphoning considerations. Another way to view the flow is to consider the solution's surface skin to be elastic, like a balloon, and anchored at the top of the well. As liquid is intentionally pumped from one well to the other, it stretches the skin down in the depleted well, and allows it to relax upwards in the receiving well; in reaction (and in the absence of external pumping), the surface tension draws the liquid back into the depleted well to relax the stretched skin.

Under the conditions explored on a **Micralyne Standard Chip**, flow driven by Laplace pressure was found to be ~ 10 to 20 times larger than siphoning flow, and on the order of EOF (0.4 - 0.8 mm/s vs. 0.6 mm/s for EOF at 150 V/cm). Using a standard cross injection protocol on this chip, Laplace pressure was found to cause backflow from the sample waste reservoir into the separation channel, which in turn caused an increase in background fluorescence signal.

Micralyne, a pioneer in microfluidics, has significant know-how in effectively addressing such issues when developing and manufacturing microfluidic devices. We encourage you to contact us for more information or, to read more on this specific topic, please refer to the following publication:

H. John Crabtree, Eric C. S. Cheong, Daryle A. Tilroe and Christopher J. Backhouse, "Microchip Injection and Separation Anomalies Due to Pressure Effects," *Analytical Chemistry* 73, 4079-4086 (2001).

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