"Challenges in Microfluidic Product Development"

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Our facility is located on Rancho San Pedro, a land grant from King Carlos III to the Spanish soldier, Juan Jose Dominguez, in 1784. The Dominguez family continues to own and lease the property where our building is located. In fact, they once owned the entire Los Angeles river estuary which is now the Port of Los Angeles. Once oil was discovered in this region, it became an industrial area full of refineries and large-scale chemical operations...the stuff of classical chemical engineering.

During my drive into work I pass large holding tanks and arrays of large diameter pipes with valves and pumps that snake up and around in a mysterious confusion. I can't tell where the inlets and outlets are, but I do see the venting which results in steady plumes from scrubbing operations. From a roadside view along the Los Angeles River (now a concrete wash), I enter our office park and into an environment where very small reservoirs and a complex array of channels with pumps and valves are managed with pneumatic controllers on small plastic cards the size of a credit card.

The mis-match in scales and the physics at these two scales cause me to ask, what's the same? What's different? In one world I'm like an ant, in the other I am a giant. In one world the volumes being moved are many thousands of gallons, in the other a drop of water. Yet the purpose is the same: transport different fluid streams, combine them to create a new stream, and move them to a final output destination.

From a physics point of view, the key difference is that gravity is the main force acting on the liquid in a large volume fluid stream, while in the microfluidic regime, while gravity still has an influence, it is not the main force; surface tension and viscous drag play a larger role. As the dimensions get smaller, these surface forces become greater than gravitational forces. In short, surface area to volume is the key difference in the behavior of fluids in the macro and micro regime.

How do these forces at the macro and micro scale impact design and engineering considerations?

It turns out a great deal! We cannot transfer the same design and engineering principles across these two scales.

In the macro regime, the bulk properties of the materials drive the design and manufacturing considerations. Understanding the heat capacity, the coefficient of thermal expansion, the phase diagram of the liquids, and the thermal and material properties of the transfer pipes are among the many parameters critical for the design of the chemical plant. We don't need to consider how we are going to make the pipes to meet the demands of the system, we can use well known design principles and manufacturing processes, depending on the service requirements of the system.

Not so in microfluidic device design considerations!

There are two aspects to consider in microfluidic device design; the surface properties of the material being used and its impact on the physics of fluid movement, and the method of manufacture which influences the geometric features available. If sharp corners are required for functional performance, end mills and micromachining may not be the right process for creating a molding tool, and injection molding itself may put further constraints on the geometry that can be realized in the device. While all the manufacturing methods used in MEMS are well understood and create exquisite precision, it is cost prohibitive unless the manufacturing volumes exceed the multiple millions.

Unlike bulk properties, surface properties vary along the length of a channel, and even small "bumps in the road" from particles or a region with a residue from manufacture can lead to unwanted air bubbles and incomplete filling, influencing the fluid behavior in unpredictable ways. Some of these effects can be mitigated with modifications of the liquid or post treatment of the channels to homogenize the surface properties. Yet none of these influences can be modeled and are critical in considering the choice of channel and feature geometry.

Further complicating the engineering, each method of manufacture has its own set of design rules which are driven by the tools and processes used in that manufacturing process. Design rules for glass etching, and silicon etching are different, which are different from the tools and processes used for injection molding and different again from roll to roll manufacturing processes. Yet all of these processes play a role in the manufacture of microfluidic devices.

Compounding the complexity is the fact that most microfluidic cartridge designs require the use of mixed materials and components, hence more than one manufacturing method is needed to create the range of functionality required. Therefore, multiple assembly processes are also required to bring dissimilar materials and components together.

The crowning aspect to this complexity is the need for biological reagent storage and stability within these devices to meet a typical shelf-life of one year. Reagent storage in devices is a field unto itself, an art that depends on the nature of the reagent, the surface, and concoction used to stabilize the active components.

But wait there's more! All of this functional performance is required at a price point of $5.00 US or less, putting aside the 'holy grail' of $1.00 US that has for so long permeated the discussion of point of care product development!

This daunting array of engineering considerations easily explains the long development cycles for these products.

With over 15 years of experience, and a team of industry experts, ALine can address these challenges and ensure you get to market faster, working side by side with you applying our fluid circuit solutions. We help you to address the real challenges in your microfluidic product development – the **Assay**!

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