It's a Material World, and I'm a Materials Girl

By Dr. Leanna M. Levine, PhD
President, ALine, Inc.

What happens between a surface and a fluid stream can lead to foul play. That's why I'm a materials girl. The complex physics and chemistry of surfaces is an important consideration in any product development, and is particularly important for microfluidic systems where the high surface area to volume 'concentrates' the effect of the surface. The choice of materials should be taken into consideration during the early design of microfluidic devices to enable applications including cell culture, immunoassays, or nucleic acid amplification.

With sophisticated workflows for immuno-analysis, materials impact assay sensitivity, limit of detection, fluid circuit functional performance, and shelf-life. This is because antibodies stick well to lower energy surfaces, such polystyrene. In cell culture applications, material surface properties can be a matter of life and death, and any leachates from bonding materials can activate cells to begin apoptosis or programmed cell death. For nucleic acid amplification, the issues arise not with the charged nucleic acid molecules being amplified, but, with the reduced activity of the enzyme.

Fluid handling in the device is also impacted by the surface properties. The material surface energy can provide enhanced performance with capillary fill, or create variability if the surfaces have residue from fabrication or do not come from a supplier providing a certificate of conformance. Examples would be the presence of mold release from injection molding, cleaners use to polish machined parts, or debris left from any of a number of cutting tools, including laser cutting, or machining. Hydrophilic surfaces, offered by a few suppliers such as 3M, and Adhesives Research, are frequently used to affect capillary fill and metering of samples or reagents.

Choices for mitigating the effect of surfaces is a tradeoff between cost and complexity. In many cases, the simplest solution is to add other mediators, such as the serum albumins (BSA), or any of a number of polyethylene glycols (PEGs), which when used in excess concentration, effectively foul the surface instead of any active components in the reagent mixture. Likewise, bumping up the concentration of enzymes and active components helps, too. Adjusting the reagent composition is likely the most direct path to increasing performance. Added development will be required if you plan to dry the reagents into the device. In addition, materials that are purchased with their native properties, and for which the design of the fluid functions is insensitive to the surface over a large range of operating conditions, provides the lowest cost, and most robust solution.

In cases where ultra-sensitivity or enhanced functional control and performance is desired, especially for in vivo (e.g. in whole blood where you don't want platelet activation), or special cell culture applications, imparting chemistry to the surface can be done with covalent linkages created through various methods, including chemical vapor deposition in a vacuum chamber, or plasma treatment with controlled gas mixtures at atmospheric pressure. These processes add cost and complexity to the manufacture, but provide a surface tailored for specific functional attributes. With chemical functional groups on the surface, specific chemical linkages with reagents or secondary surface modifiers can be made with good control. Other methods of controlling surface properties includes the application of a coating and then curing it in place, a common practice in catheter manufacture. Finally, nearly all the methods used to improve the adhesion of bonding materials, whether corona, plasma, or flame, all impart some hydrophilicity to the material. But the shelf life of such treatments is variable, not only due to variations of the treatment conditions, but on the polymer itself. In general, more crystalline polymers will retain surface treatment longer, since the chains have less mobility.

For single-use product applications, avoiding costly treatments to native materials through the design strategy on the fluidics side, and solution modifiers on the reagent side, is the first strategy. If surface treatment is a preferred strategy, then treating the materials before assembly reduces variability. Being able to tailor function by using mixed materials, is also a robust strategy for cartridge development. Using bonding methods that allow assembly of mixed materials facilitates this approach.

This is where being a materials girl comes in handy. Experience with successful products in the marketplace; we stock a well-vetted collection of materials for the most common microfluidics applications. We purchase from qualified vendors with lot control, even in the early development stages. This avoids surprises later during scale up. (Don't worry, other surprises will crop up). We stock materials which have a track record of performing well in applications ranging from mammalian cell culture to immunodiagnostics. Most of our supplier relationships go back more than 10 years. The table below describes the materials we stock which are commonly used in disposable cartridge development.

It's a material world, and on the surface, a lot can happen!

Material	Thickness Range	Applications	Specification
Cast Acrylic	0.050mm – 2.0mm	PCR, imaging, cell culture, fluorescence Detection	Close tolerance, cast, optical quality
COC/COP	.050 mm – 1.0 mm	PCR, Imaging, Fluorescence	Optical quality, UV transparent
Polycarbonate	0.125 mm - 0.250 mm	PCR, imaging, cell culture	Optical grade std tolerances +/- 5%
Polyester	0.012mm – 2.0mm	Channels, interface with electrochemical sensors Immunoassays	Wide range of thicknesses, hydrophilic surfaces
FEP, PTFE	0.025mm – 0.125mm	Various, where hydrophobicity desired	Close tolerance
Polystyrene	0.050 mm	Immunoassays/gas permeable	Either top of bottom of chamber.
Silicone	0.050 – 1.5mm	Cell culture/gas permeable	Medical grade, Pt cured
Urethane	0.025 – 0.125	Gas permeable/diaphragm valves	Compatible across all application types
Polypropylene	0.50mm – 1.5mm	PCR, cell culture	Compatible across all application types
Glass	0.130mm – 1.1mm	Microarray substrates/DNA	Silanized/plasma activated
Silicon	0.5mm – 1.0mm	Microarrays/CMOS/etc	Wire bond /encapsulated
Silicone PSA	0.025 – 0.090mm	PCR, cell culture,	no leachates/optical
Acrylic PSAs	0.025-0.250	Immuno assays/cell culture	Optical/low leachates
Epoxy	n/a	Cell culture/PCR/Immuno	Medical grade, UV cure
Direct Bond	various	Polycarbonate, Acrylic, COC	Solvent or plasma pretreat, heat & pressure