

Position Paper: Applications in Microfluidics

Fred K. Forster

Department of Mechanical Engineering
University of Washington, Seattle, Washington 98195-2600

Scope: After a very active decade of research in microfluidics, applications conceived and demonstrated are arguably as varied as those in the macrofluidic world. And just as the last two centuries of progress in the microfluidics has seen progress dependent on advances in virtually all fields of engineering, we should expect the same to be true in microfluidics. But even though most research is evolutionary and not revolutionary, future needs in this area are not easily forecast. With those caveats, it is the purpose of this report to identify the most important areas that would better enable progress in microfluidics.

Problem Definition: along with myriad uses for microfluidics including biological and chemical processing, biotechnology, nanotechnology, hydraulic actuation, power generation and heat transfer, have come road blocks that must be dealt with before many exciting applications in these areas are practical. While significant progress can usually be demonstrated on a limited number of samples, material gaps usually exist between proof of principle and proof of practicality. The technology gaps are usually in either of two basic categories, generic fluidic components and systems integration. Often the primary means to address these needs are part and parcel of a research team not well-equipped to tackle them.

If one, somewhat naively, categorizes microsystems into two basic categories, the problems confronting researchers can be more clearly seen. Consider, on one hand those devices that are designed to take advantage of the microscale, such as electroosmotic transport and electrophoretic molecular separation systems, e.g. Systems developed at caliper technologies. For this technology one can utilize macroscale system elements to support the few components that are required to be of small scale. On the other hand systems may be designed in spite of small scale limitations, such as the swallowable imaging capsule made by given imaging, israel, in which all components have severe size constraints. This is a great example even if not considered a microfluidic device! It is this latter category of microfluidic devices that present the biggest challenge to miniaturization. They require the marriage of currently incompatible components and a victory over miniaturization for each subsystem. For “classic ”MEMS devices, system integration implies only mechanical subsystems integrated with electronics. In general, however, microfluidic MEMS devices require that plus the fluidic subsystems, which complicates the situation substantially.

But in addition, i/o of fluid is significantly more difficult that i/o of electrical signals and fluid is substantially more difficult to manipulate that electrons. It is for these reasons that the growth curves of commercial microfluidic market should not be modeled after growth data for the electronics industry!

Potential Solutions: the enabling technologies for the realization of new and practical microfluidic devices are in the areas of generic components and integrating 1) mechanical

actuators, 2) driving electronics, 3) sensors and 4) signal electronics. Integration entails CAD and advances in fabrication.

Even with good current efforts in developing CAD tools, the current state of the art is just keeping up with new component processing ideas in such areas as mixing, and separation techniques, coming out of research laboratories. At the current rate of progress, a system that can be designed with existing CAD tools is already obsolete. CAD is presently limited to investigation of a narrowly defined aspect of a system to evaluate a limited number of parameters. The ability to utilize such tools to design complete fluidic systems made up of components need more effort.

Even if a complete design is well understood, the problem of integration is still a major challenge due to material incompatibility and, it follows, a lack of fabrication facilities capable of such integration. From our experience with a reasonably straight forward pump design whose fluidic aspects (performance and simplicity) are outstanding, incorporation of on-chip circuitry for piezoelectric actuation (high voltage) and feedback flow control based on pressure transducer (low level signals) is severely limited by available fabrication techniques. While no one expects to build fluidic systems out of individual generic component ,this level of integration is necessary before more complicated monolithic fluidic systems can be achieved. If packaging research was supported hand-in-hand with center for microfabrication whose charter was to provide both fabrication and packaging service to microfluidic researchers, mechanisms would exist for substantial progress in the field.

As stated above and at the top of the list of enabling technologies is generic fluidic components. Although having been studied extensively, pumps, valves and connectors are still considered to be a far-from-finished story. Current approaches to valves and connectors suffer from limitations of microfabrication, and, in addition valves suffer from the same actuation problems that haunt "classic "MEMS Research on such subsystem components should be encouraged and well-funded.

Summary: Only through substantially more effort in communication,such as this Work hop provides, can the intrinsic interdisciplinary problems associated with manufacturing of MEMS be defined in a complete enough fashion to solicit solutions. This paper addresses the need for center that can service the research community with expertise in both microfabrication and packaging. In addition, research into improved generic microfluidic devices should be encouraged.