

Applications of Microvalves in Centrifugal Microfluidics

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Introduction

New avenues for low-cost point-of-care (POC) diagnostics have emerged thanks to centrifugal microfluidic platforms (CDs). They are now widely used in a variety of diagnostic procedures, including blood plasma separation, serial dilutions and those requiring polymerase chain reaction steps. The use of CD microfluidic devices makes it possible to transfer a wide range of intricate processes that, in the past, required trained personnel and expensive individual laboratory equipment to the small disc platform. The CD fluidic platforms portability, ease of use, integration and robustness necessitate fluid flow control designs that are straightforward, dependable and scalable. On a centrifugal platform, valves are essential for opening and closing microfluidic channels, allowing for precise fluid flow control.

Description

In addition, valving systems are absolutely necessary for isolating chambers from the rest of a fluidic network at the appropriate times, effectively directing the reagents to the desired location, performing serial dilutions and integrating multiple other processes on a single CD. In this paper, we go over the various fluidic valving systems that are available, talk about how they work and assess how well they work with CD fluidic platforms. Based on their actuation mechanism, which may be mechanical, thermal, hydrophobic/hydrophilic, solubility-based, phase-change, or any combination of these, the presented valving systems are categorized as either "active," "passive," or "hybrid." The governing physics, their actuation mechanism, performance variability, the required disc spin rate for valve actuation, valve response time and other parameters are all important topics that are discussed. The pertinence of certain sorts of valves for particular capabilities, for example, reagent capacity, stream control and different applications is summed up [1].

For POC diagnostic platforms, centrifugal microfluidic devices (CDs) were successfully implemented. POC systems are platforms that can be used outside of a centralized laboratory, either at the patient's bedside or in a medical office. By accelerating the time to diagnosis and eliminating the need for repeat patient visits if the tests can be performed during the initial doctor's visit, they aid in reducing the turnaround time for patients and doctors to receive the test results, thereby contributing to improved patient outcomes and lowering treatment costs. These POC systems are durable, portable, inexpensive and simple to use, even for personnel with a moderate amount of training. The centrifugal platform for the first time in 1972, many different processes, such as immunoassays, environmental monitoring, analyte detection, serial dilutions and a plethora of other ones, now make use of CD technology, which has come a long way. Since introduced the disc-based platform LabCD in the late 1990s, numerous academic and industrial teams have published a steady stream of articles on how to adapt centrifugal microfluidic platforms for a variety of

diagnostic applications. These applications range from enzymatic assay analyzers and specialized modules for disc-based immunoassay microarrays to the characterization of pollutants in environmental samples, the detection of antibiotic resistance on a CD platform.

The advancements in fidelity and dependability of microfluidic valving, a crucial fluidic operation on a spinning disc, supported the active developments and enhancements in CD technology that occurred over the course of the previous twenty years. Fluid flow is controlled, channel paths are turned on and off, specific chambers are isolated and chambers are opened for the controlled sequential release of reagents. At first, only so-called "passive valves" like siphon, capillary and hydrophobic valves were used. Most of these passive valves were based on the opposing action of capillary forces (controlled by the material of the disc and the geometry of the microfluidic channels) and centrifugal forces (controlled by the angular velocity of the disc and specific position and geometry of the microfluidic channel) on the CD. They did not require any peripheral equipment to be actuated, were easy to make and were simple to use [2].

The spin speed, the geometry of the channels and chambers, the location of the vents on the discs (which allow the pressure in various microfluidic chambers to be equal to the ambient pressure), the type of native material on the disc and the various coatings that are used to alter the wetting angle of the liquid on the surface all affect how passive valves operate. According to their controlling parameters such as spin speed, vent-hole geometry, suction, channel divergence, concentration gradient, presence of siphon channels and inclusion of dissolvable films. Researchers and engineers have gradually come to the realization that manufacturing flaws, minute variations in the bill of materials and the shelf life of materials have an effect on passive valves reliability and repeatability as CD devices began to be used in commercial applications outside of academia. Active valves were introduced to address issues with passive valves robust operation. Some external subsystems are used by active valves to trigger and actuate the fluidic channel's opening or closing. The typical active valve actuation mechanisms, such as laser, magnetic, diaphragm-based, electrical, thermal, mechanical and pH-controlled actuations; and other valve actuation mechanisms are also summarized [3].

At last, there is still one more kind of valves, alleged "crossover valves" that use components of both dynamic and aloof valves. The ferrowax capillary flow-driven valve, the microheater activated valve and other similarly actuated valves are all examples of hybrid valves. Although the platform's microfluidic system's native capillary forces serve as the foundation for these valves, external equipment (such as a hot plate or laser) is required for their activation that causes the solid wax plug to become liquid. The fluidic channel is opened and the plug can move once the phase transformation transforms it into a liquid. In comparison to passive valves, active and hybrid valves typically have quicker response times and are more dependable. The operational parameters of valves, such as response times, fabrication routes and manufacturing cost, are all discussed in detail. Readers will gain a deeper understanding of how to select the right valve for their particular application thanks to this information.

The present basic survey centers on the creation and use of micro valves on outward microfluidic stages. In addition to discussing the virtual prototyping of numerous types of micro valves implemented on centrifugal microfluidic platforms, our work continues and updates more general reviews of micro valves on lab-on-chip platforms. For a wide range of complex chemical and biological assays, centrifugal microfluidic platforms offer a number of advantages; however, the precise and robust valving capability of CD fluidic devices is necessary for their reliable operation. A comprehensive list of the microvalves that have been reported in scientific publications is provided in this

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Received: 01 August, 2022, Manuscript No. fmoa-22-83440; Editor assigned: 03 August, 2022, PreQC No. P-83440; Reviewed: 16 August, 2022, QC No. Q-83440; Revised: 22 August, 2022, Manuscript No. R-83440; Published: 29 August, 2022, DOI: 10.37421/2476-2296.2022.9.245

critical review. Based on their actuation mechanisms, the valves have been divided into active, passive and hybrid categories. For each type of valve, we provide a description of the actuation mechanism. We examine the similarity of the valves to application on divergent stages and report (at whatever point known or conceivable to assess) the additional expense to execute these valves [4].

The geometry of the fluidic network on the disc and the physio-chemical properties of the disc's materials control the critical burst frequencies of passive valves on CDs, which are actuated by the disc's spin rate, spin direction, or spin acceleration. As a result, changes in the disc's material properties (such as changes in humidity or exposure to air) or the dependability of the action of passive valves is impacted by minute alterations in channel geometry that result from manufacturing flaws. However, in order for the active valves to operate, external force and energy must be applied to the valve. Magnetic force, laser, various heaters, pneumatic force and other forms of external actuation are just a few examples. Active and passive valve components are combined in the hybrid valves; For instance, the wax is melted by an external heat source and carried by a capillary force toward the fluidic channel that becomes impassable when the wax solidifies [5].

Conclusion

By reviewing the variety of valve options on centrifugal platforms, we hope that the reader will be able to select the type of valve that is most suitable for a particular spin regime and the necessary application of an upcoming assay.

In many instances, the advantages of passive valves in terms of cost and portability outweigh the disadvantages of active valves in terms of reliability. We may see a greater prevalence of active valves on centrifugal assay platforms when they are developed to be even less expensive to implement and when external actuation mechanisms, such as lasers, will not significantly increase the platform's cost or weight.

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How to cite this article: Gilbert, Riley. "Applications of Microvalves in Centrifugal Microfluidics." *Fluid Mech Open Acc* 9 (2022): 245.