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Design and implementation of fluidic micro-pulleys for flow control on centrifugal microfluidic platforms

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Abstract Microfluidic discs have been employed in a variety of applications for chemical analyses and biological diagnostics. These platforms offer a sophisticated fluidic toolbox, necessary to perform processes that involve sample preparation, purification, analysis, and detection. However, one of the weaknesses of such systems is the uni-directional movement of fluid from the disc centre to its periphery due to the uni-directionality of the propelling centrifugal force. Here we demonstrate a mechanism for fluid movement from the periphery of a hydrophobic disc towards its centre that does not rely on the energy supplied by any peripheral equipment. This method utilizes a ventless fluidic network that connects a column of working fluid to a sample fluid. As the working fluid is pushed by the centrifugal force to move towards the periphery of the disc, the sample fluid is pulled up towards the centre of the disc analogous to a physical pulley where two weights are connected by a rope passed through a block. The ventless network is analogous to the rope in the pulley. As the working fluid descends, it creates a negative pressure that pulls the sample fluid up. The sample and working fluids do not come into direct contact, and it allows the freedom to select a working fluid with physical properties markedly different from those of the sample. This article provides a demonstration of the "micro-pulley" on a disc, discusses underlying physical phenomena, provides design guidelines for fabrication of micro-pulleys on discs, and outlines a vision for future micro-pulley applications.

Keywords Hydrophobic fluidics · Centrifugal microfluidics · Micro-pulley · Syphon · Inward flow · Pressure change

1 Introduction

The field of centrifugal microfluidics has greatly evolved since its birth about 50 years ago (Burtis et al. 1972; Kido et al. 2007; Kirby et al. 2012; Gorkin et al. 2012a). Many functional techniques for processing chemical and biological samples and controlling fluid flow (such as valving, lysing, mixing, separation/clarification, metering, volume definition, and heating/cooling) have been developed to integrate biological/chemical assays onto these microdevices (Steigert et al. 2006; Cho et al. 2007; Mark et al. 2012). These efforts have led to the creation of integrated platforms that are called "Lab-on-disc" (Madou et al. 2006) in contrast to stationary "Lab-on-chip" platforms. Both Lab-on-disc platforms and Lab-on-chip devices share a common goal to function as fully automated and integrated sample-to-answer devices for chemical and biomedical applications, including biological assays (Madou et al. 2006; Ducree et al. 2007; Gorkin et al. 2010b).

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