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Fluidic Control with Wax Valves for Paper-based Diagnostics

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ABSTRACT

Paper-fluidic devices are a common platform for point-of-care disease detection in under-resourced areas because of their low cost and minimal instrumentation requirements. Limited fluidic control in paper-fluidic devices has hindered the incorporation of multistep reactions that are necessary for more sensitive disease detection. One potential fluidic control mechanism is the incorporation of thermally actuated wax valves to separate assay stages. Such valving would expand the detection capabilities of these devices by permitting fluid obstruction for sustained reactions and facilitating controlled volume release within a fully-automated, self-contained device. Despite the potential to exploit wax valves for innovative paper-fluidic diagnostics, a thorough, quantitative analysis of how they can best be used has not been performed. Here, in parallel macroscopic and microscopic analyses, we show that wax valves' geometry and surface area in paper test strips influence flow behavior when thermally actuated. Macroscopic analysis evaluated the flow rate past the valves of the visible fluid front across the width of the membrane; microscopic analysis used particle image velocimetry to evaluate trends in particle flow before and after valve actuation. Preliminary results indicate that geometry and size influence valve opening times and the rate of fluid flow past the valves. Future analyses will compare the macroscopic and microscopic velocity profiles in various assay spaces and times to provide quantitative insight to the inner workings of paper-fluidic devices. This information will facilitate intelligent and efficient design of multistep paper-fluidic detection technologies with potential applications in lateral flow immunoassays, two-dimensional paper networks, and other point-of-care diagnostics.

KEYWORDS

Lateral flow assay, multi-step, fluidic control, paper fluidics, flow analysis