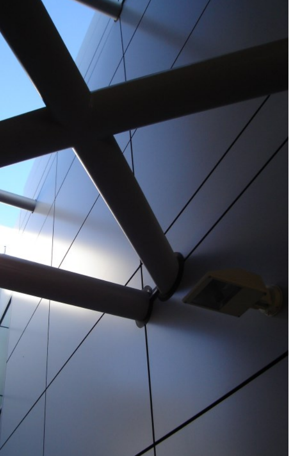

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of

Carlos Castro

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Imbibition in Paper-based Microfluidic Devices

Doctor of Philosophy, Graduate Program in Mechanical Engineering
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Dr. Hideaki Tsutsui, Chairperson

Point-of-care technologies provide innovative solutions that improved treatment. Healthcare systems including some low-resource settings have begun implementing these technologies providing the convenience and reduction in large lab set-ups. But many low-resource setting do not have the means or infrastructure to perform these tests. Low-cost is one of the main driving components when it comes to point-of-care diagnostics. Paper-based microfluidics has generated a great amount of interest for the development of diagnostic and self-contained analytical devices. Satisfying the World Health Organization's (WHO) recommended ASSURED criteria; Affordable, Sensitive, Specific, User-friendly, Rapid and robust, Equipment free, Deliverable), paper-based microfluidics have made point-of-care testing more accessible. Applications range from healthcare, food safety, environmental monitoring, among others. What has in part attracted attention is the low-cost, ease-of-use, and adaptability of these paper devices. Compared to conventional microfluidic devices, the paper-based counterparts are able to utilize paper's inherent wicking property to eliminate the external pumping needed to drive the fluid. Channels are easily formed by either selectively removing sections of the paper substrate or by pattering channel boundaries with a hydrophobic material.

In spite of the benefits and advantages described above, paper-based microfluidic technologies often lack the necessary sensitivity and sophistication available in conventional microfluidic devices. In order to be a competitive alternative, paper-based microfluidics require improvement and novel development of feasible detection methods. These methods will likely require increasingly complex chemistry and control of reagents. Thus, understanding imbibition as well as obtaining precise, accurate, and consistent fluid handling within the paper device will be crucial.

Although considerable knowledge exists on techniques to manipulate fluid within the paper channel, what is lacking are studies on how non-laboratory conditions (e.g. relative humidity) influence fluid flow. This presentation aims to address this gap with particular focus on the effects of relative humidity and channel width. A series of controlled imbibition experiments is reported using cellulose papers commonly used in the field of paper-based microfluidics. We show that both the imposed relative humidity and the channel width have critical design considerations in paper-based devices. Additionally, we compare three models, the L-W model, the Fries et al. (2008) model which incorporates evaporation, and a newly developed water saturation model. We assess their accuracy in representing the experimental data and systematically evaluate the importance of evaporation and water saturation under a wide range of relative humidity conditions. The current study has created a library of paper-specific, imbibition-related properties for commonly used filter and chromatography papers for the first time.

Collectively, the success of this research will improve the development of future diagnostic and analytical paper devices producing a user-friendly and cost effective point-of-care alternative.

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