

Accepted Manuscript

Heat release at the wetting front during capillary filling of cellulosic micro-substrates

A. Terzis, E. Roumeli, K. Weishaupt, S. Brack, H. Aslannejad, J. Groß, S.M. Hassanizadeh, R. Helmig, B. Weigand

PII: S0021-9797(17)30683-5
DOI: <http://dx.doi.org/10.1016/j.jcis.2017.06.027>
Reference: YJCIS 22454

To appear in: *Journal of Colloid and Interface Science*

Received Date: 17 May 2017
Accepted Date: 7 June 2017

Please cite this article as: A. Terzis, E. Roumeli, K. Weishaupt, S. Brack, H. Aslannejad, J. Groß, S.M. Hassanizadeh, R. Helmig, B. Weigand, Heat release at the wetting front during capillary filling of cellulosic micro-substrates, *Journal of Colloid and Interface Science* (2017), doi: <http://dx.doi.org/10.1016/j.jcis.2017.06.027>

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.



Heat release at the wetting front during capillary filling of cellulosic micro-substrates

A. Terzis^{a,1}, E. Roumeli^{b,c}, K. Weishaupt^d, S. Brack^a, H. Aslannejad^e,
J. Groß^f, S. M. Hassanizadeh^e, R. Helmig^d, B. Weigand^a

^aInstitute of Aerospace Thermodynamics, University of Stuttgart, 70569 Stuttgart, Germany

^bDepartment of Engineering and Applied Science, California Institute of Technology, 91125 Pasadena, USA

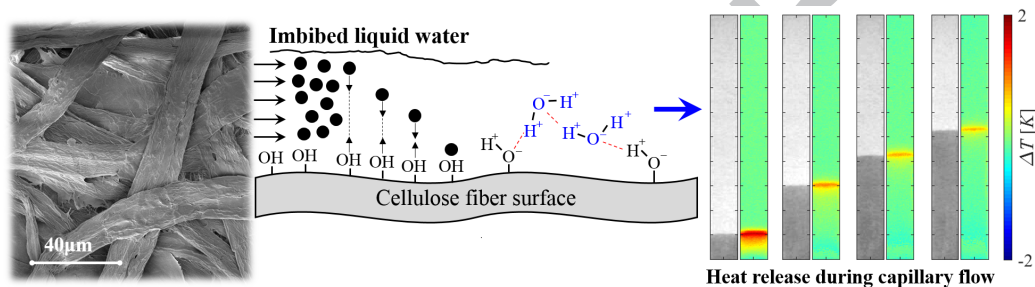
^cDepartment of Mechanical and Process Engineering, ETH Zurich, 8092 Zurich, Switzerland

^dDepartment of Hydromechanics and Modelling of Hydrosystems, University of Stuttgart, 70569 Stuttgart, Germany

^eDepartment of Earth Sciences, University of Utrecht, 3584 CD Utrecht, The Netherlands

^fInst. of Thermodynamics and Thermal Process Engineering, University of Stuttgart, 70569 Stuttgart, Germany

Abstract



Spontaneous imbibition in cellulosic materials is an expanding field of research due to the direct applicability in paper-based microfluidics. Here, we show experimentally, using simultaneous thermal and optical imaging that the temperature at the wetting front during capillary filling of paper is temporarily increased, even if the imbibed fluid and the cellulosic substrate are initially at isothermal conditions. Several liquids and two types of filter paper, characterised by scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis, were investigated demonstrating a significant temperature rise at the wetting front that cannot be neglected from the process. The temperature rise is found to be related to the energetics of imbibition compounds, including acid-base contributions, that result in electrostatic attractions as the liquid molecules are adhered on the fiber surfaces upon capillary contact.

Keywords: paper-based microfluidics, thermodynamics, capillary dynamics, interfacial energy

1. Introduction

Since their establishment as a medical diagnostic tool [1, 2], paper-based microfluidics received a tremendous attention from physicochemical, biomedical and engineering scientists resulting in a multi-discipline research field that has been regularly reviewed [3–7]. The functionality of such devices is based on the ability of paper as a porous medium to transport liquid spontaneously due to capillary action driven by interfacial energy differences [8], as thermodynamics drives all systems to a lower energy state.

The capillary filling of paper is, however, a complex transport process that involves strong adsorptive interactions at the molecular scale. For substrates that are mainly composed of natural cellulosic fibers [9, 10], this is associated with the interactions between the imbibed fluid

and the available cellulose chains which have their free hydroxyl groups (OH^-) in an equatorial orientation in the glucopyranose rings [11, 12], and hence, readily available for bonding (see cellobiose-inset in Figure 1). The abundance of polar hydroxyls in these regions results in a chemical polarity that can even align cellulosic derivatives when exposed to an electric field [13–15] while measurements of surface energy evidenced that cellulose fibers are biased towards an electron-donor behaviour [16–20]. That is why cellulose, similar to silica surfaces [21], can be used as a strong adsorbent material [22–24].

At the micro-scale, during capillary filling of paper, a precursor liquid film [25] has been shown to move slightly ahead of the wetting bulk phase onto the fiber surfaces forming a kind of liquid slippage [26]. This is believed to have a direct relation to wettability [27] and depends on the mobility of the first adsorbent liquid-layer molecules that occupy the low energy positions of the solid [28, 29]. For short range forces, and based on electron transfer the-

*corresponding author. Tel.: +49 (0) 711 685-62315

Email address: alexandros.terzis@me.com (A. Terzis)

Download English Version:

<https://daneshyari.com/en/article/4984778>

Download Persian Version:

<https://daneshyari.com/article/4984778>

[Daneshyari.com](https://daneshyari.com)