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Open microfluidics (OM): state of the art and perspectives

Jean Berthier
CEA Grenoble,France

Open-surface fluidics has started in the mid 1900's triggered by space applications. In space, gravity is negligible and surface tension and capillarity forces are the dominant forces. Fluids can be moved along solid structures by capillary forces, without being confined inside a duct. Such features are called "vanes" as described in "Capillary flow experiments for the International Space station". The open boundary with the surrounding air is the reason for the denomination: Open Microfluidics of the "average friction length" parameter. In particular, it is shown that the use of Washburn law where the radius of the tube is replaced by the hydraulic radius is misleading. Experimental and numerical examples are shown, pertaining to rectangular and triangular open grooves and to thread-based microfluidics. The concept of "Open Microfluidics" (OM) also concerns biotechnology and thermics. In biotechnology, at micro and nano-scales gravity is negligible before surface tension and capillary forces. The emergence of portable diagnostic systems—called Point-of-Care—using capillarity to move the biologic fluids—usually human blood—has triggered new theoretical developments of OM. Liquids can even be moved in channels devoid of ceiling and bottom. This configuration is called "Suspended Microfluidics". Liquids can also be moved by imbibition in fibers, such as cellulose (paper-based microfluidics) or nylon (thread-based microfluidics). In thermics, open microflows are used to cool down heating systems by evaporation; the thinness of the capillary films triggers fast evaporation and cooling. Hence OM is now a platform for many different applications. In this work, we present a very simple condition to determine whether a fluid can be moved in arbitrary open configuration, based on the wetted and free perimeters and on the liquid-fluid contact angle. We have called this condition the "generalized Cassie law". We also generalized the Washburn law for capillary dynamics in a cylindrical tube to open morphologies, showing the importance. Finally, the new concept of two-phase open capillary flows is presented. In particular it is shown that a plug cannot stop a capillary flow in a uniform cross section channel. It is also shown that only three typical plug configurations exist in such flows.

jean.berthier@cea.fr

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