Dew droplets are seen on spider webs in the early morning. Small ones remain pinned on the threads while larger ones slide down the grid, fuse with others, leave smaller droplets in their wake, and eventually fall from the web. Spontaneous motion, coalescence, and division are words that describe the behavior of droplets on fiber networks. An on/off transition is observed when a droplet comes around an intersection between several fibers: large droplets cross the junction while small droplets remain pinned. We show that fibers perform advantageously most operations of digital microfluidics, such as multiplexed biochemical microreactions: intersections are the basic component of fiber-based microfluidic devices. © 2009 American Institute of Physics.

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when $\nu$ is decreased below 20 cS. In the high-viscosity regime (where $Bo^*$ is independent on $\nu$), the time spent to cross the intersection increases and diverges as $Bo^* \rightarrow Bo^*$, as often in physics when a potential barrier is just crossed. As seen in Fig. 3(b), the droplet may be significantly delayed; the delay time is proportional to the droplet viscosity.

This blocking/crossing sharp transition is particularly interesting to perform on droplets those elementary operations often encountered in microfluidic devices. In that sense, it is the analog of T-shaped junctions in channel-based microfluidics.\textsuperscript{10} For example [Fig. 4(a)], small reactive droplets may meet together at a junction between fibers and perform a chemical reaction. By setting several nodes in series, a droplet can be divided into a large number of microdroplets, as easily as ever [Fig. 4(b)]. The large droplet crosses every intersection but leaves a tiny droplet at each of them. Moreover, the coating film on the vertical fiber transforms into pearls (Plateau instability) that are collected at each node. As an example, a single droplet ($\Omega \approx 2 \mu$L) has been divided into 44 microdroplets on a network made of 40 $\mu$m fibers in about 1 s.

Among others, it is also possible to encapsulate an aqueous droplet by an incoming oily droplet [Fig. 4(c)]. A number of applications require multiple microreactions to be performed in parallel, e.g., drug discovery, gene-expression analysis, and high-throughput assays. With basic operations described in Fig. 4, multiplexing is...
easily performed: the substance to be tested is placed on \( N \) nodes by using operation \( \text{H}_2\text{O}_8\text{N} \text{b} \), then the \( \text{H}_2\text{O}_8\text{N} \text{b} \)-device is rotated by 90° and markers are placed on the \( N \) vertical (previously horizontal) fibers. The biochemical reactions are made thanks to operation \( \text{a} \) and the result may (or not) flow down and be analyzed.

Fiber-based microfluidic devices present numerous advantages over existing technologies (pressure-driven droplet convection into microchannels, manipulation of droplets on a chip through electrowetting, etc.). The operations described here above are robust to the physico-chemical properties of the liquid of interest. They only require the liquid to wet the fiber, which is easily satisfied by using adequate fiber materials or by adding surfactant molecules. Contrary to the planar laboratories-on-a-chip, the geometry of fibers allows the design of fully three-dimensional networks with many fibers bringing multiple reactants to the same point. It also reduces the contact between droplets and solid parts; the loss of liquid through coating is minimized, especially since the coating pearls are also collected. Therefore, a millimetric droplet can be divided into tens of microdroplets on a fiber network. Thanks to the sharpness of the blocking/crossing transition, the volume of a droplet that leaves a node is accurately controlled. Although high-rate multiplexing may be performed with channel-based microfluidics\(^{11}\), it often requires synchronization of the droplets conveyed into various channels, which is achieved through high-tech micropumps. Here, there is no need for any external synchronization: droplets wait for each other on the nodes. Moreover, there is no risk of denaturing the biochemical content of the droplet due to prohibitive electric fields generated by electronic components. Finally, fiber networks are simple to use, reusable, zero-energy consuming, and practically costless.

In this letter, we have discussed the behavior of droplets on fiber networks. The motion of a droplet on a fiber is driven by a balance between gravity and viscous friction. The observed long-term deceleration is due to the loss of mass by coating the fiber. When encountering an intersection between two fibers, small droplets remain pinned while large droplets cross the junction. The blocking/crossing transition occurs for a threshold volume, which results from a balance between gravity and capillary forces. With its specific behavior, the intersection between two fibers is the basic component of fiber-based microfluidics. Simple networks can perform elementary operations on droplets, such as coalescence, division, multiplexing, and encapsulation. The fiber-based microfluidics is proved to be a promising alternative to existing technologies that may be of interest for a number of biochemical, medical, and food-industry applications, e.g., low-cost medical diagnostic, DNA analysis, cell cultivation, drug discovery, and high-throughput assays.

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