Obstacle race of air invading biomimetic leaves

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In case of drought, the water in the xylem hydraulic circuits of trees falls down to very negative pressures. Cavitation bubbles can nucleate, initiating an air embolism that propagates, a process called air-seeding, leading to the failure of the water circulation. Observations on real leaves showed that the embolism advances by a succession of long stops and sudden jumps.

To understand the nature of jumps, we propose an experimental model using biomimetic leaves in silicone (PDMS), made of thin water-permeable membranes [1,2]. The veins of these artificial leaves are channels filled with water, and here we have introduced constrictions to mimic the pit in between real leaf channels (figure 1).

We observed that the jumps after each constriction are due to the sudden release of an elastic deformation of the channels, occurring when the meniscus is pinned and evaporation continues. The jumps of the meniscus can reach directly the next constriction (when it is nearby, as is the case in Fig 1b) or can reach the inside of next channel and are followed by a slow progression of evaporation (Fig 1a). For large number of constrictions, the pinning at the first constriction induces a long waiting time before the first jump, while the second waiting time is much smaller and the subsequent waiting times increase slowly until the complete drying of the channel. A simple model enables to capture this stop-and-go dynamics, and is successfully applied to quantitative data extracted from experiments realized with real leaves of the fern Adiantum.

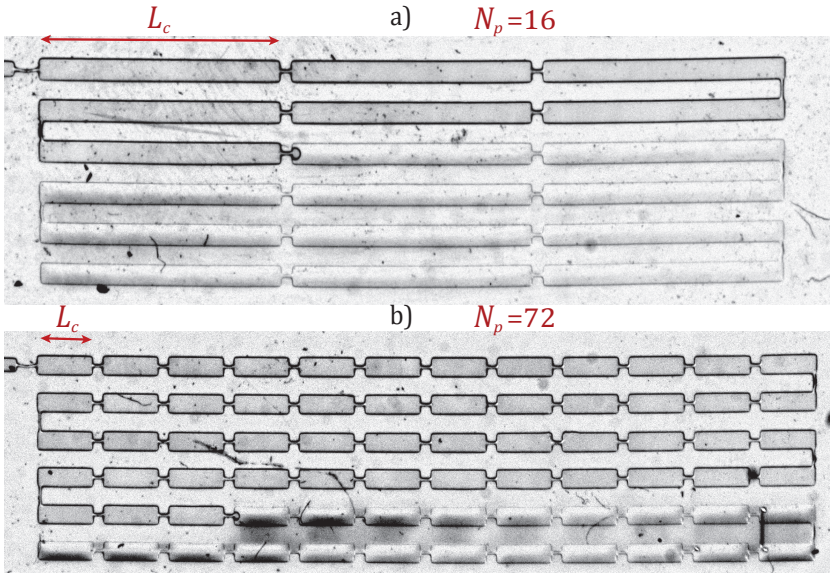

Figure 1: Long channel with a series of N_p constrictions. The air invasion starts on the top left entrance, the rest of the dead-end channel is prefilled with water. Evaporation occurs through a thin PDMS membrane covering the channels.

References

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