Stick-Slip Behavior: Evolution of a Condensation Pattern with a Humidity Sink

Mathan K. Raja, and Wenceslao González–Viñas
Dept. of Physics and Applied Mathematics, Universidad de Navarra, Pamplona, Spain

Breath figures (BF) are patterns of condensed droplets on a substrate in contact with supersaturated vapor. Its dynamics has been studied long ago [1]. If we set, prior to the condensation, a hygroscopic NaCl drop on the substrate, the salty drop acts as a humidity sink absorbing most of the available water vapor in the surroundings [2]. The depleted humidity near the salty droplet inhibits the growth of pure water droplets and defines the region of inhibited condensation (RIC). Previous studies attempted to understand the complex interplay between the growth of salty and water droplets experimentally [2]. Here, we report numerical simulations validated against the interpretation of experimental findings. Our model enables us to simulate the controllable characteristics and conditions in contrast to constraints that arise from the experimental setup.

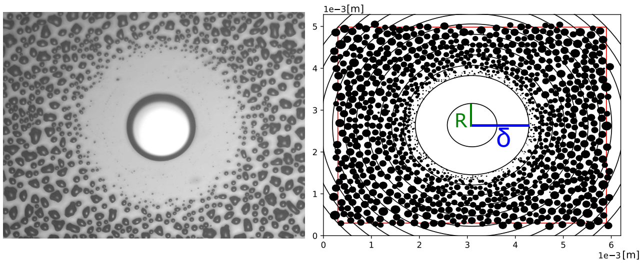

Fig. 1. (Left) Experimental image of breath figure with the salty droplet in the center [2] captured from the top with a horizontal field of view of 4.4 mm, and (right) numerical simulation with δ region of inhibited condensation (RIC) and radius R of the salty droplet.

The initial conditions of the simulation are set by experimentally derived parameters such as the flow rate of humid air and the rate of nucleation. The substrate design is modeled with periodic boundary conditions, and additional droplets are included near the boundary to eliminate edge effects. The coalescence events take place in parallel to the simulation event on the droplet population recursively when any droplets overlap. The state of all the components in the simulation for any given time step is captured for further detailed analysis.

Competition for resources: In our simulations, physical objects operate independently but are interconnected through resource availability and previous outcomes. The availability of humidity estimated using interpolation of shared vapor concentration by the existing population governs the nucleation model, growth of salty and water droplets. Nucleation events are contingent on nucleation rates determined by the resource availability of the seed site, selected from a random pool.

Stick-slip-like dynamics: Dilution of the salty droplet alters the region's vapor concentration profile, affecting the growth dynamics of the droplet population. This change is not gradual or evenly distributed. Initially, there is a rapid decline in δ, followed by prolonged plateaus (fig. 3). Water droplets compete for resources, diminishing the sink effect of the salty droplet over the period. Even with constant humid airflow, regular stick-slip-like dynamics manifest in both experimental and simulation models.

In conclusion, our presentation will provide additional analysis to elucidate the intricate interplay among the key components based on our simulation results [3].

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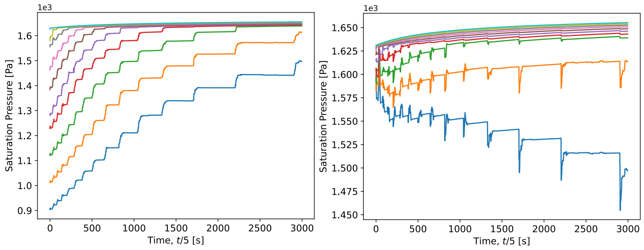

Fig. 2. Eulerian observation(left) of adaptive humidity reveals increased availability away from the salt droplet. Lagrangian observation(right) of δ evolution demonstrates BF's effect on humidity profiles. Forefront rings (green, orange, blue) capture reduced saturation pressure when facing the salty droplet.

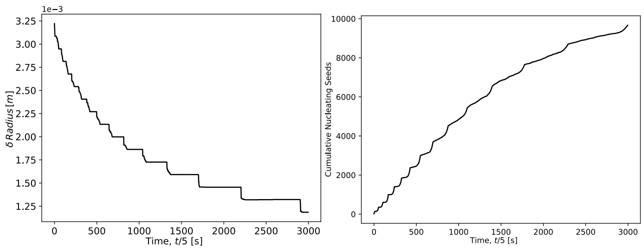

Fig. 3. In our simulation, the cumulative nucleating seeds (right) and the evolution of the δ (left) display regular stick-slip-like dynamics, similar to what was observed in [2], but the underlying cause remains unexplained.

[1] D. Beysens, *Dew nucleation and growth*, C. R. Phys. 7, 1082 (2006), and references therein.

[2] J. Guadarrama-Cetina, R.D. Narhe, D.A. Beysens, W. González-Viñas, *Droplet pattern and condensation gradient around a humidity sink*, Phys. Rev. E 89, 012402 (2014).

[3] Mathan K. Raja, R García-García, W. González-Viñas. *In preparation*