# Contact line friction of bubbles

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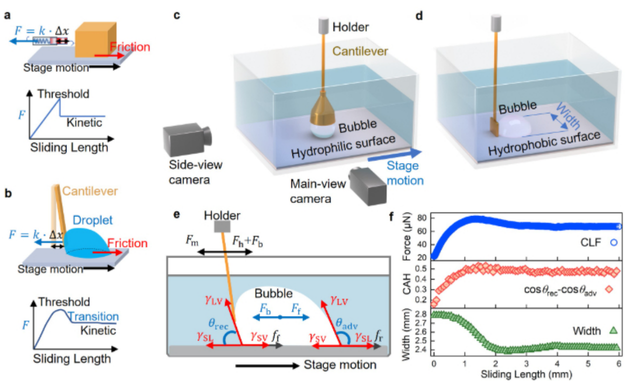
Contact line friction (CLF) of bubbles is ubiquitous, from bubbles on a beer glass to $H_2$ bubbles sliding over electrodes in electrolysis. However, a fundamental understanding of CLF of bubbles is still missing, mainly due to the challenge of precisely controlling bubble sliding. For example, it is not clear how bubbles start sliding and how CLF of bubbles depends on velocity. We therefore developed a bubble friction force instrument to directly measure bubble CLF. This force develops from a static regime, through a transition, to a kinetic regime. This entire process is quantitatively described by a modified Kawasaki-Furmidge equation. Bubble CLF was measured for velocities from 0.2 μm/s to 2 mm/s, revealing a transition from a constant CLF regime below about 60 μm/s to a velocity-dependent CLF regime on surfaces with various wettability. The velocity dependence stems from interfacial adaptation governed by the liquid ionic environment with a relaxation time of around 10 μs. Moreover, CLF of bubbles can be measured on hydrophilic surfaces and under a challenging $H_2$ atmosphere, overcoming the limitations of current droplet-based methods. Our results provide a quantitative basis for understanding CLF of bubbles with relevance to many applications, including bubble manipulation and electrochemistry.




*Schematics of CLF measurements. a, b, Setup and force curve of solid-solid friction (a) and droplet–solid friction (b). c, d, BuFFI for hydrophilic (c) and hydrophobic surfaces (d). e, Forces acting on the cantilever and bubble. f, Typical measurement results on a fluorinated silicon wafer.*

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