Adhesion Force Measurements of Contact Lines Pinned at Edges

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It is well known that the three phase contact lines of bubbles and droplets on solid substrates can be pinned by sharp edges. For example, although a liquid droplet on a smooth surface will roll when the surface is inclined above a certain angle, a droplet in contact with an edge on the same surface will roll at a higher angle. Similarly, an air bubble in liquid that can slide along a smooth solid surface may be pinned at a scratch. Although this effect is exploited in a variety of devices and experimental techniques, there has not been any previous quantitative investigation of the force required to detach a contact line from an edge. In this study, the force required to detach a three-phase contact line pinned at a well-defined edge is measured directly. In addition to understanding the behavior of contact lines at edges, such measurements could also shed light on the wetting of rough surfaces or surfaces with defects.

To measure the force required for contact line detachment, atomic force microscopy measurements were performed using modified colloidal probes. The colloidal probes consist of 3-5 µm diameter silica and polystyrene spheres. The probes were modified by focused ion beam milling to produce an edge around their circumference (see Figure 1 below). Edges were produced in various positions above and below the equilibrium contact line position for unmodified particles, as determined by the particle contact angle. The use of this geometry allows for direct measurement of the detachment force and contact angle hysteresis of the interface pinned at the edge.

![Figure 1: Silica colloidal probe (a) before and (b) after modification. The edge is at an angle to compensate for the inclination of the cantilever when mounted during measurements.](image)

Force measurements are performed with an atomic force microscope as the colloidal probes approach and are withdrawn from air-water and water-air interfaces. From these measurements, it can be observed that the contact line is pinned at the edge rather than at the equilibrium position for an equivalent spherical particle. The force at which the particles detach from the interface is also different due to the difference in contact line position and contact angle in comparison to a contact line on a smooth probe. From these measurements, the force per unit length required to detach the particles from the edge can be determined, as well as the contact angle hysteresis at the edge.