Wetting angle hysteresis in microdrops

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Received October 1, 2001

The characteristic time of substrate plastic deformation due to surface tension forces of a liquid drop is estimated. The equilibrium conditions of a drop of varying volume on the convex ledge formed due to the deformation have been analyzed under account for partial relaxation of the elastic stresses. Contribution of those stresses to the wetting angle hysteresis (about 3°) has been estimated and the hysteresis value has been shown to increase for very small drops mainly due to reduction of the retreating angle caused by a strong substrate deformation. The hysteresis contribution to the decrease in the observable wetting angle of microdrops under evaporation attains significant values (about 10 to 16°).

Произведена оценка характерного времени пластической деформации подложки силами поверхностного натяжения жидкой капли. Выполнен анализ условий равновесия капли изменяющегося объема на образовавшемся в результате деформации выпуклом ранте, с учетом частично релаксировавших упругих напряжений. Приведена оценка их вклада в явление гистерезиса смачивания (~3°) и показано, что для капель очень малого размера величина гистерезиса увеличивается, в основном, за счет уменьшения угла оттекания, вызванного значительной деформацией подложки. Отмечено, что вклад гистерезиса в уменьшение наблюдаемого краевого угла смачивания испаряющихся микрокапель достигает существенных значений (~10–16°).

The specific surface energy of a small particle is known to depend on its size. The dimension dependence of the surface energy, σ_l, for a liquid phase can be revealed, for example, by measurement of wetting angle (related to σ_l by the Young equation as well as by considering the drop evaporation process that for small drops occurs at a rate proportional to $\exp(\sigma_l/r)$ [1, 2]. In this case, the experimental points of the evaporation curve show wave-like deviations from a smooth dependence. In works aimed at the direct wetting angle measurements, θ variations about 10 to 15° are also observed while the convolution and photometry methods used have an accuracy about 3 to 5° [2]. In both cases, it is just the wetting hysteresis that may be responsible for such deviations. The essence of this phenomenon consists in that the wetting perimeter becomes fixed, thus changing substantially the liquid drop behavior in some circumstances, e.g., during its evaporation. The purpose of this work is to consider reasons for this effect for microdroplets as well as to estimate the wetting hysteresis effect on the drop-substrate system parameters.

The wetting hysteresis was studied in several works [3, 4]. It is just the microscale irregularity and the substrate nonuniformity that are believed to be main causes of that effect [4]. Numerous assumptions used in those works, however, are invalid to microdroplets, e.g., the microirregularity height of about 1.25 μm. In some systems, the wetting perimeter fixation is attained due to the mutual dissolution of liquid and solid phases [4]. Nevertheless,