



Infrared visualization of thermal motion inside a sessile drop deposited onto a heated surface

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ABSTRACT

Drop evaporation is a basic phenomenon but the mechanisms of evaporation are still not entirely clear. A common agreement of the scientific community based on experimental and numerical work is that most of the evaporation occurs at the triple line. However, the rate of evaporation is still predicted empirically due to the lack of knowledge of the governing parameters on the heat transfer mechanisms which develop inside the drop under evaporation. The evaporation of a sessile drop on a heated substrate is a complicated problem due to the coupling by conduction with the heating substrate, the convection/conduction inside the drop and the convection/diffusion in the vapor phase. The coupling of heat transfer in the three phases induces complicated cases to solve even for numerical simulations. We present recent experimental results obtained using an infrared camera coupled with a microscopic lens giving a spatial resolution of 10 μm to observe the evaporation of sessile drops in infrared wavelengths. Three different fluids fully characterized, in the infrared wavelengths of the camera, were investigated: ethanol, methanol and FC-72. These liquids were chosen for their property of semi-transparency in infrared, notably in the range of the camera from 3 to 5 μm . Thus, it is possible to observe the thermal motion inside the drop. This visualization method allows us to underline the general existence of three steps during the evaporating process: first a warm-up phase, second (principal period) evaporation with thermal-convective instabilities, and finally evaporation without thermal patterns. The kind of instabilities observed can be different depending on the fluid. Finally, we focus on the evolution of these instabilities and the link with the temperature difference between the heating substrate and the room temperature.

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1. State of the art

Drop evaporation has been widely investigated theoretically [1], experimentally [2,3] and numerically [4]. Generally, the work deals with either drops with small sizes [5,6] or flat drops which can be comparable with films [7]. Table 1 summarizes numerous studies of drop and droplet evaporation performed since 1973; most of these studies discuss physical mechanisms related to the evaporation dynamics. Scientific production has sharply increased since 1995. Indeed, drop and droplet evaporation is involved in many industrial processes and in many heat and mass transfer applications. The literature evidences that the main physical mechanisms driving droplet evaporation are the following:

- the heat transfer by conduction in the substrate,
- the heat transfer by convection [temperature gradients induces superficial tension gradients (Marangoni effects) and normal convection],

- the liquid/substrate molecular interaction at the roughness scale that tends to modify the wettability of the drop for a given drop volume,
- the vapor mass diffusion around the drop.

In spite of the considerable activity attested by the large quantity of publications, the dominant mechanisms acting on the kinetics of drop evaporation are not well understood because of the strong coupling between the various phenomena. In the studies of drop evaporation, two approaches can be distinguished: drop evaporation either with [13,18] or without [15] wall heating. Without wall heating, the drop evaporation dynamic is slower compared to the heating situation. Also, the wall heating enables a higher evaporation flow rate inducing a high temperature gradient inside the drop; this last situation is useful when working with a given infrared resolution.

In an unsaturated atmosphere and without overheating from the substrate, the mass diffusion of the vapor in the gas surrounding the droplet can become the limiting phenomenon of evaporation kinetics. According to the experiments of Shahidzadeh-Bonn et al. [30], such a phenomenon is much more pronounced for organic fluids than for water, this being mainly due to the difference of densities

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