From single droplet impact to micrometric droplet chains: scaling the effect of surface topography

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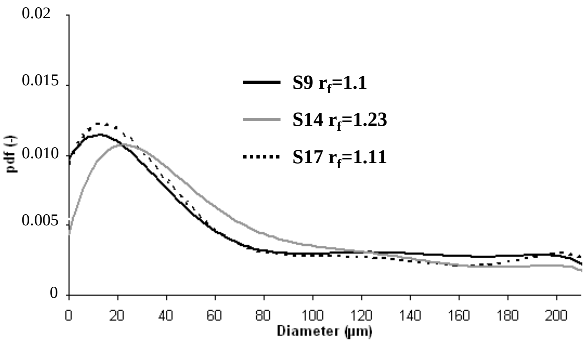
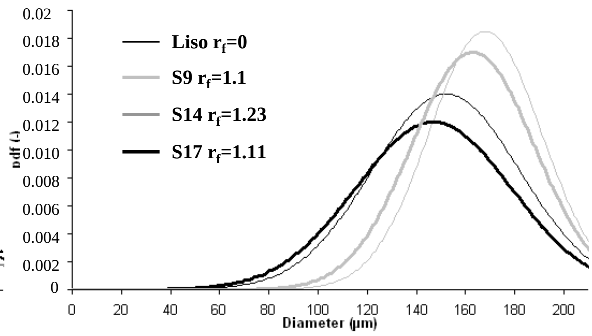
Abstract

Droplet/wall interactions have been widely explored within the last decade to develop smart interfaces and enhanced surfaces to obtain an accurate control of heat and mass transfer, which is vital, for instance for cooling applications (*e.g.* [1]). Most of the studies reported in the literature address the wetting and spreading behaviour of millimetric droplets, in a trial and error approach to infer on the best wetting and/or topographical characteristics providing the desired control of the spreading behaviour and of the heat transfer mechanisms. The present work follows the experiments reported in Moita *et al.* [2, 3] where criteria have been proposed to develop a systematic methodology to design micro-structured surfaces able to increase the rate of heat removed by single droplets impacting onto hot surfaces. The experiments reported here start with millimetric droplets ($2.5<D_0<3.3$mm) and follow an approach to scale down the patterns to micrometric droplet applications ($80\mu m<D_0<340\mu m$). The surfaces are made from silicon wafers and are micro-patterned with square pillars; the boundary conditions at impact range from dry to wet and the impact velocity, U_0, from 0.88 to 7m/s. The thermal behaviour is inferred from the local heat fluxes, determined from instantaneous temperature measurements made at the droplet-surface interface with fast response thermocouples. These are related to the way that the micro patterns affect the spreading diameter. One of the side effects of modifying the surface topography is to trigger secondary atomization. This is particularly relevant in micro-droplet stream applications and must be well controlled. Hence, the experiments make use of a Phase Doppler interferometer combined with a high speed camera to characterize the secondary atomization generated at droplet impact. The analysis allows to find that, in the homogeneous wetting regime, the parameter $r_f=(2l+\lambda_R)^2/[(2l+\lambda_R)^2+8lh]$ provides the best criterion to optimize the design of the micro pattern when, both, millimetric and micrometric droplets are considered. Here l, λ_R and h stand for the side of the square area, height of the pillars and pitch (distance between them) respectively. Within the film boiling regime, the effect of the topography is clearly more evident. However, with the current surfaces the experiments are on the limits of applicability of Wenzel's theory, so a further scaling down is required. Analysis of the size probability distribution of secondary droplets generated at the impact (Figures below), suggest that large surface patterns act to promote dynamic disintegration which overcomes the thermal induced one, so that the rougher surface leads in fact to smaller secondary droplets.





PDF of the secondary droplet size resulting from the impact of a monosize stream of ethanol droplets (D_0=180μm, U_0=3.2 m/s) over the micro-textured surfaces (Liso to S17) within: **a)** nucleate boiling regime ($T_{w,0}$=130°C) **b)** film boiling regime ($T_{W,0}$ =200°C). PDA measurements performed at r=1.2mm, z=1.2mm.

References

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[3] Moita, A.S., Tatta, M., Moreira, A. L. N., *24th ILASS-Europe, Lisbon, Portugal* (2011).

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