Extremely high Leidenfrost temperature on nanoparticle-deposited surfaces and its influences on quenching phenomena

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1. Introduction

We recently found that quenching behavior of various dilute nanofluids is nearly identical to that of pure water, but due to nanofluids boiling during the quenching process, some nanoparticles deposit on the surface of the rod, which results in much higher quenching rate in subsequent tests with the same object. However the traditional concept of conduction-controlled quenching cannot explain the acceleration provided by the nanoparticle layer on the surface. In this study, we study effects of nanoparticle deposition on evaporation and rewetting of a single sessile droplet of water. Leidenfrost temperature closely associated with the quenching phenomena is investigated on clean and nanoparticle-deposited surfaces by measuring total evaporation time of a droplet. The possible mechanisms responsible for the quench acceleration on the nanoparticle-deposited surfaces will be discussed with the relation between the localized rewetting of the heated surface even above the Leidenfrost temperature and the destabilization of the film-boiling vapor film.

2. Methods and Results

2.1 Experimental

To study the effects of nanoparticle deposition on quenching heat transfer, the following measurement are of interest.

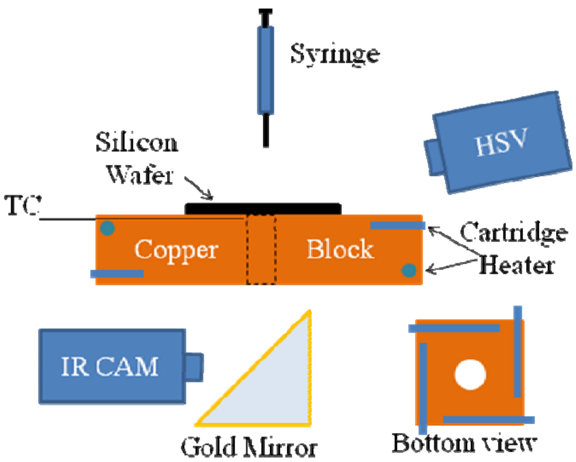

Fig. 1. Schematic of sessile droplet experimental setup

First, the static Leidenfrost of the water on silicon surface will be determined by measuring evaporation time of water droplet as function of silicon wafer temperature. The temperature with longest evaporation time (above boiling point) is defined as the static Leidenfrost. Second, dynamic Leidenfrost point, which is defined as the temperature at which the droplet completely rebound, could be determined using high speed visualization.

Figure 1 shows the schematic of single droplet quenching experiment. The sample substrate of interest seats on top of the copper block and the temperature of the substrate could be assumed to be very close to the block temperature. The syringe on top of the sample is used to drop water droplet. The through-hole of 1.0 cm diameter in the copper block is the window for the IR signal, which is reflected to the IR camera using a gold coated mirror. The high speed camera (HSV) is located as angle from the horizontal surface of the sample.

2.2 Results

We obtained a considerable increase in T_{Leid} by 260 K. From a comparison of wetting phenomena on fresh and alumina nanoparticle-fouled Si wafers at ΔT_{sat} = 270K in Fig. 2, obviously the nanoparticle layer disturbs formation of stable vapor film. It was also revealed on the fouled surfaces that heterogeneous nucleation of bubbles initiated at very initial moments of the impact and continuously occurred at several local positions. This indicates that the nanoparticle layer serves good condition for nucleation and contains some local features to promote liquid-solid direct contact and phase change of liquid, resulting in such a high Leidenfrost point.

REFERENCES

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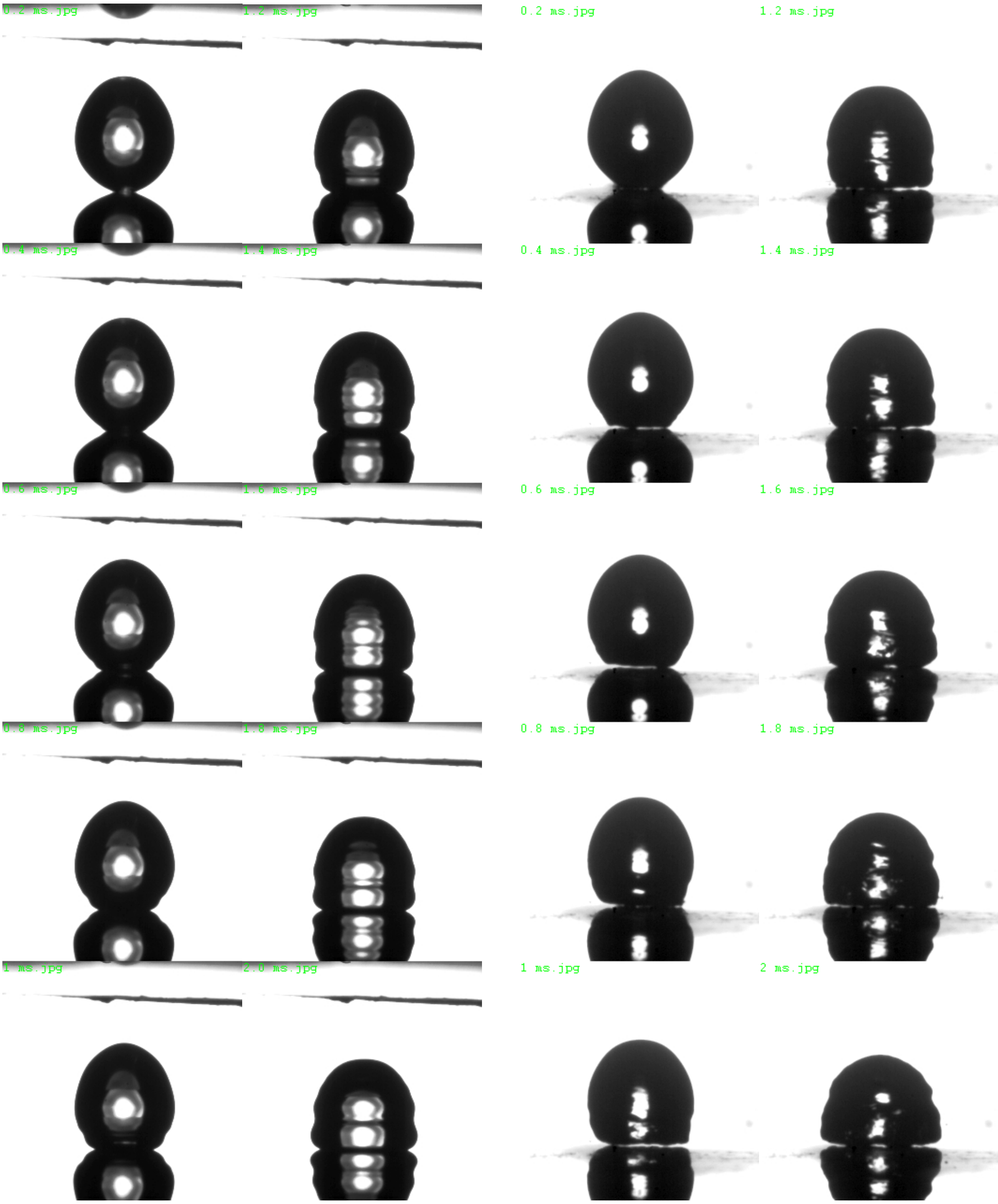

(a) (b)

Fig. 2. Wetting pictures of a water droplet at ΔT_{sat} = 270 K with Δt = 0.2 msec. (a) fresh Si surface; (b) alumina fouled Si surface.