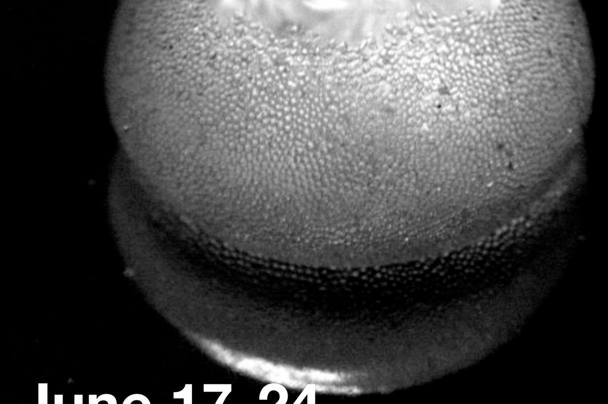

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Self-coverage of Leidenfrost droplets

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Introduction

Zero wetting can be obtained when a droplet is placed on a hot solid surface. Beyond a critical temperature that depends on the liquid and the substrate properties, the droplet **levitates** on its own vapour. The Figure 1 shows such a droplet in the **Leidenfrost state**, coined according to the name of the first observer [1].

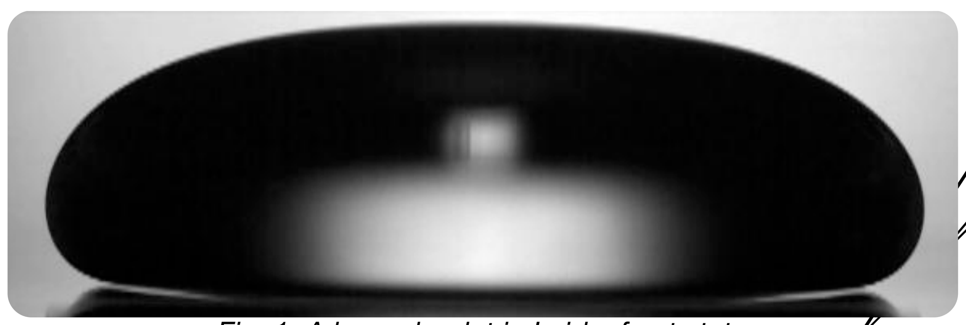

Fig. 1: A large droplet in Leidenfrost state

A large number of very nice papers concerns the case of pure liquid [2,3]. On the other hand, the interaction of such a droplet and particles is to be studied regarding applications like smart **cleaning**, small object **transport** [4], particle **deposition** [5], **encapsulation** [6]...
This work concerns basic observations of glass beads included in a Leidenfrost droplet. We particularly studied how the particles organized in the droplet during the evaporation and how the particles are released when the water is fully gone.

Observations

Glass (transparent) or basalt (black) beads were used. Their diameters were between 90 and 150 µm. A given mass of particles were dropped in a large droplet when it was in Leidenfrost state (Fig. 2 top, basalt grains were used). At the beginning, the particles are located at the bottom of the droplet. During the evaporation of the droplet, we observed that the grains are **trapped by the surface** and form a layer that climbs the droplet side. Figure 2 shows the evolution of the layer during the evaporation. The bottom picture shows the droplet just before being completely covered. Fluorescein was added to increase the contrast.

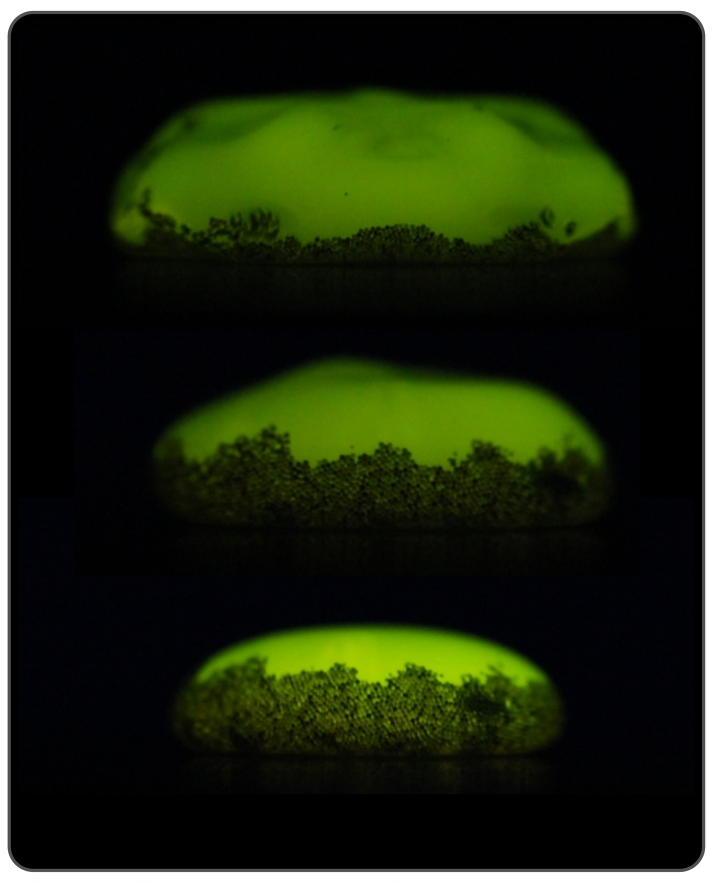

Fig. 2: Evaporating Leidenfrost droplet in which basalt grains were introduced.

Monolayer coating

During the evaporation process, the radius of the droplet was monitored using a camera either placed to capture the side (Fig.3a) or the top (Fig.3b) of the droplet. While the first allows to determine the volume, the latter allows to capture the coating of the droplet by the beads.

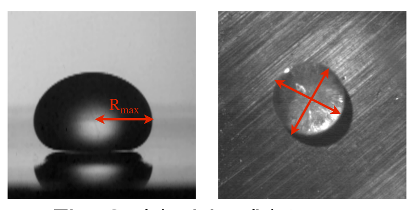

Fig. 3: (a) side, (b) top

We compared the time variation of the radius seen from the top of droplet made of water and made of water + 15 mg of grains at Fig. 4.
The droplet containing grains **evaporates slower when grains are present in the droplet**. Moreover, we observed that the apparent radius of the droplet is blocked by the presence of the grains. This occurs just after the complete coverage of the droplet by the grains (full circles). The red curves found in Fig. 4 is a fit using Biance's model [2]. To fit the water+grain droplet, the model has to be multiplied by a factor 1.2.

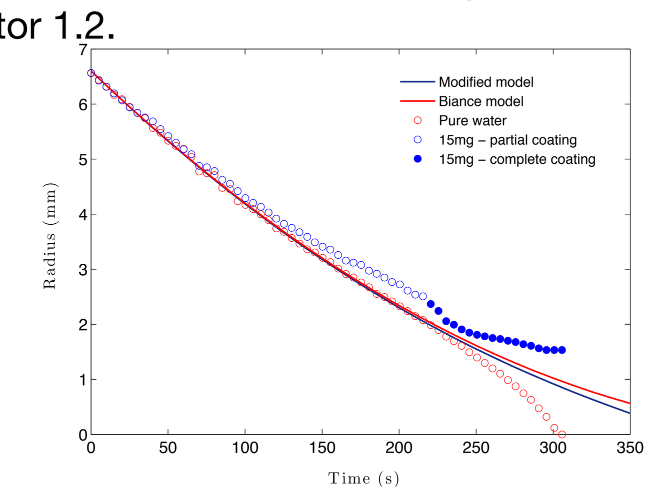

Fig. 4: Time evolution of the apparent radius of a droplet made of water and made of water+grains

When the droplet was completely covered, we measured the surface S of the droplet. We estimated that the grains occupied 80% of the surface. It is then possible to estimate the number of layers

$$N_{layers} = \frac{N_b \pi R_b \phi}{S}$$

R_b N_b: radius and number of beads
ϕ : surface fraction

The calculated values are reported in Fig. 5 for different sizes of grains. We conclude that the grains formed a **monolayer** at the moment of the total covering.

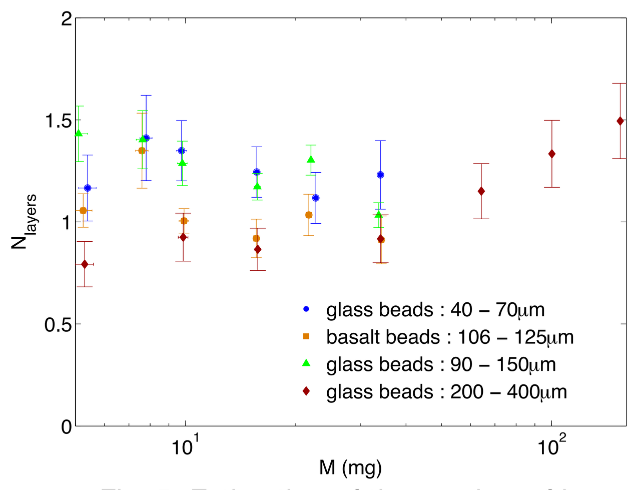

Fig. 5: Estimation of the number of layers of grains when the droplet is totally covered.

Final state

After being totally covered, the droplet keeps on evaporating until all the water is gone.
According to the amount of grains in the droplet, two situations are encountered :

A. Small amount of grains

The grains form a small sphere like a **blackberry**. The density has been estimated to be 0.4 which is very low.

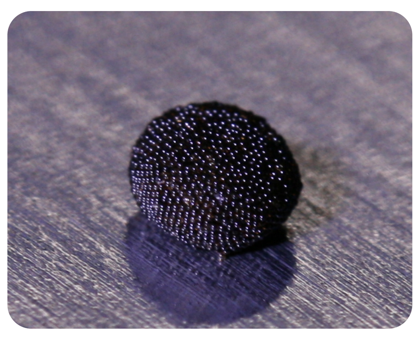

Fig. 6: Blackberry made of basalt beads

B. Large amount of grains

The monolayer of beads buckles and/or collapses. The result is an object that looks like a droplet. One of these objects was observed using a microtomography device that allowed to investigate the structure of the evaporation result. The object presents **voids** and is recovered by a **dense layer of grains**.

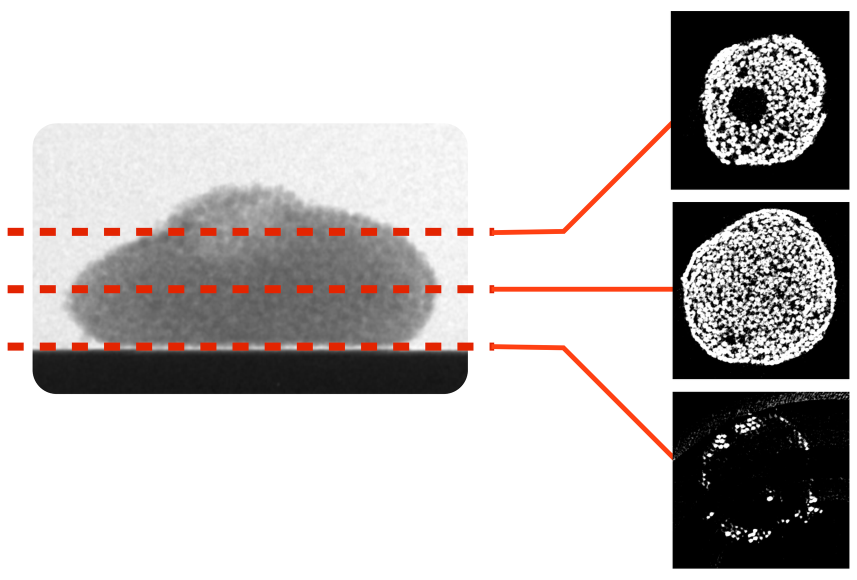

Fig. 7: X-Ray microtomography of the aggregation of glass beads after complete evaporation of the water.

The final state is characterized by a low density object. The nature of the cohesion is still to be determined

Conclusion

The presence of beads in a droplet in Leidenfrost decreases the evaporation rate. The grains (which are hydrophilic) move towards the droplet surface to be trapped. The grains form a monolayer that completely covers the droplet. The situation is similar to liquid marble obtained with hydrophobic grains [7]. After this stage, according to the number of grains, the dried beads form a sphere with a low packing fraction or an object containing voids.

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