BREATH FIGURE OF WATER AND OIL AND THE STRUCTURE PATTERN FORMATION

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Summary Experimentally, we mix water and $C_6H_{18}OSi_2$ vapors at room temperature. We stream the mixed vapors into a condensation chamber where previously is set a thin glass coated with 3M ECG-1700 which it is a repellent to both substances. The temperature of the substrate is maintained at 5 °C to achieve the dew condition for the mixed vapors. We observe the dropwise aggregation of oil around the water droplets. For certain configuration of fluxes a structure formation is observed. The evolution of the radius average of the BF is reported for both substances. The contact angle for water and oil are respectively 92° and 65°.

INTRODUCTION

The phenomenon of dew on a cold surface or Breath Figures has been studied since the last two decades by D. Beysens and M. Knobler [1] and P. L. Kaprivsky [2], and important advances have been developed in order to understand the formation of Breath Figures. Three stages have been observed during the BF formation: 1) the nucleation process, when the monomers of saturated vapor find a place to attach over the cold surface, 2) when no more nucleation is allowed by the surface and the remain droplets grow by condensation of the water vapor. This growth can be described by the power law $<r>\sim t^{1/3}$. And 3) when those droplets have reached their maximum size, and they start to interact each other by contact or by coalescence. In this stage it says the BF becomes self-similar or $<r>\sim t^{1}$. Also, in this last stage of coalescence, new nucleation is allowed and new population of droplets are possible to detect. This phenomenon is also observed with other volatile liquids like the silicon oil ($C_6H_{18}OSi_2$). The three stages take very short time because its low viscosity and its very small contact angle. The oil-water interaction has a very important place in the the emulsion industry, pollution treatments and also biological process. In this work we analyse the BF formation as the result of the mix of two vapors of immiscible substances: water and $C_6H_{18}OSi_2$. We report the values of the average of the radius as a function of time for both substances. The structure formation by the dropwise aggregation of oil around the water droplets are also reported for certain conditions of the fluxes.

Experimental setup

Inside a Delrin® chamber is set a small and thin common glass with a surface of 12x12 mm^2 coated with 3M EGC-1700 which it is a repellent to the water and the $C_6H_{18}OSi_2$. The contact angle observed for respectively substances are 92 ± 2° and 65 ± 2°. The temperature is set on the substrate at 5 °C and it is maintained by a Peltier cell component. The saturated vapor of the both substances is produced by bubbling N_2 at different fluxes inside a separate flasks that are containing water and $C_6H_{18}OSi_2$. Then, the vapors are mixed inside a syringe at room temperature. The mix is streamed into the chamber and because the gradient of temperatures between the cold surface and the vapor, the dew conditions can be achieved. We observe through a small window with help of a inline microscope and we take snapshots of the surface every 5 s. The first case observed is the BF formation for only $C_6H_{18}OSi_2$. We streamed into the chamber a flux of 250 ml/min for almost 150 s. This time was enough to transit for all stages mentioned above. After this observation, we fixed a flux of water of 250 ml/min. While the flux of $C_6H_{18}OSi_2$ can variate from 110 to 300 ml/min. Some other observations were performed fixing the $C_6H_{18}OSi_2$ constant and varying the flux of the water vapor. A remarkable experimental fact is that the $C6H_{18}OSi_2$ can break and remove the coating from the substrate.

Observations

At initial time, the first species to condensate on the surface is the water. Then, several seconds after, the $C_6H_{18}OSi_2$ condensates independently to any value of the flux. The production of structures depends on the values of the flux of water vapor versus the flux of vapor oil: if the water vapor is maintained relatively closer to the values of the flux of $C_6H_{18}OSi_2$, it will be possible to produce cells with a more or less accurate shape, otherwise, the water droplets will increase their size and they will be maintained for a long time with the minimum interaction. To build the structures, the amount of oil vapor may increase even twice times than the water vapor flux. This is in agree with the observation of the oil ponding over the substrate that helps to the water droplets to fix a position and to reduce the interaction between each others. As a consequence of this ponding, the water droplets can increase their own size mainly by direct condensation and just the larger water droplets can interact by coalescence. That does not mean the BF of water stay for a long time in the second stage (mentioned above). It means the main mechanism of growing is the condensation. In Fig. 1, we show some samples of the experiment for different fluxes used in the experiments.

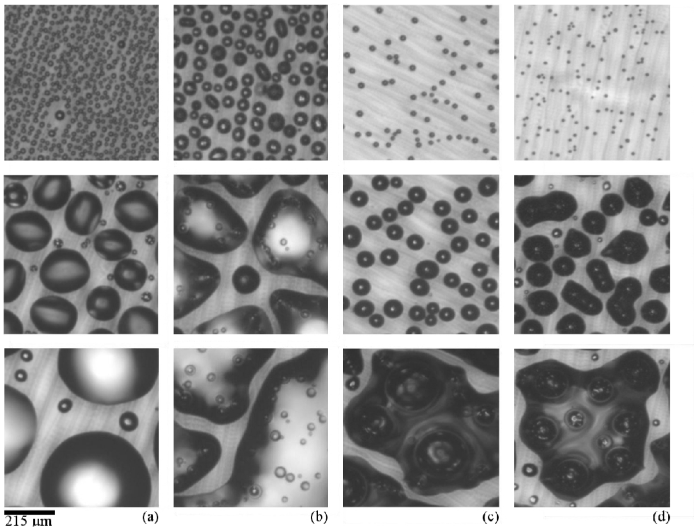

Figure 1. In column (a) we show the condensation of $C_6H_{18}OSi_2$ with a flux of 250 ml/min (the initial time corresponds to the first frame from above). In column (b) the flux of $C_6H_{18}OSi_2$ vapor is 250 ml/min and water vapor is 250 ml/min, so non structure formation is produced because the surface is too occupied by the oil without to leave enough space for the condensation of water. At the end there is a pond of oil surrounding some water droplets. In column (c) the flux of $C_6H_{18}OSi_2$ vapor is 240 ml/min. This amount of flux favourites the structure formation. It is possible to observe a big water droplet surrounded by oil with an almost hexagonal shape (the last frame down). In column (d) the flux of $C_6H_{18}OSi_2$ vapor is 230 ml/min and it is forming more defined cells.

CONCLUSIONS

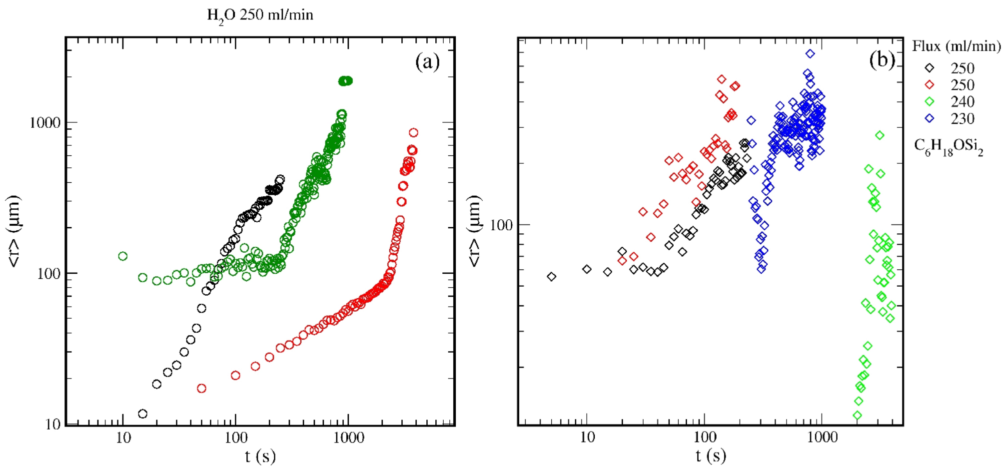

Figure 2. (a) Shows the growth of the water droplets when the flux of water vapor is fixed at 250 ml/min. We can highlight that in any case we could recover the laws of growing of $\langle r \rangle \sim t^{1/3}$. For the second stage of BF evolution $\langle r \rangle \sim t$ or the self-similar behaviour. (b) For $C_6H_{18}OSi_2$ the values of $\langle r \rangle$ do not present the typical power laws of growth. Just when the fluxe of water vapor and oil vapor are similar (diamond black) the shape of the plot is comparable with the time evolution of $\langle r \rangle$ for the case of water.

To conclude this work, to build structures cells of water droplets and oil it is necessary to balance with the dew point of each species and the amount of flux in order to leave the spaces on the surface to condensate a large population of water droplets and to leave the oil ponds around those BF. That is why the very closer fluxes (250 ml/min water and oil) does not produce cells. Other conclusion is the fact that the amount average of the radius is sensitive to the presence of other vapours like is presented in Fig. 2.

References

[1] D. Beysens and M. Knobler, Phys. Rev. Lett. Vol. 57, No 12, 1986.
[2] Yu. A. Andrienko, N. V. Brilliantov, and P. L. Krapivsky J. Stat. Phys. Vol. 75, Nos. 3/4, 1994.

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