Characterization of bubble dynamics and heat transfer processes in pool boiling under extreme wetting scenarios
Tiago Palma
tiangomesquitapalma@tecnico.ulisboa.pt
Instituto Superior Técnico, Universidade de Lisboa, Portugal
November 2016

The present work addresses the effect of extreme wetting regimes on pool boiling heat transfer, analysing the boiling curves together with detailed description of bubble dynamics. The work focuses on the use of biphilic surfaces (hydrophilic surfaces with superhydrophobic spots) although superhydrophilic surfaces are also swiftly addressed. Within biphilic surfaces similar patterns are devised with different dimensions. The patterns have squared spots of 10 mm, 5 mm and 2 mm side. Biphilic surfaces show a better performance than hydrophilic and superhydrophobic surfaces, since higher heat fluxes are usually achieved for the same wall superheat. They seem to be able to combine the best of the two regimes, having an early onset of nucleate boiling and an efficient rewetting mechanism. This is promoted by the contrast of wettability which doesn’t allow an insulating vapor layer (characteristic of superhydrophobic surfaces) to be formed, since the bubbles are confined to the superhydrophobic spot. Contact line velocity is zero, which means the bubble is stuck on the border of the spot. Bubble departing diameter is shown to be controlled by the size of the spot. The larger the spot the larger is the diameter while the lower is the departure frequency. From the various biphilic patterns tested, the best performing one has the largest superhydrophobic spot. Estimates of the heat transfer mechanisms are made which point to the fact that this surface extracts more heat than the others due to a higher vaporization rate and also due to a better rewetting mechanism.

**Keywords:** Wettability, Pool boiling, Boiling curves, Bubble dynamics, Biphilic surfaces,

1 – Introduction

Heat transfer is crucial in many engineering applications and throughout many other fields of activity. In particular, fields such as electronics, energy production or automotive industry are many times directly associated with productivity and efficiency. Cooling a system may be achieved through different mechanisms, from free and forced convection in single-phase flow to pool boiling in two-phase flow. The latter seems to show higher heat transfer coefficient (HTC) and therefore is of more interest.

The surface in which pool boiling occurs strongly affects the conditions in which it develops. Therefore, controlling surface topography and/or surface chemistry provides the means to enhance even further the HTC. One of the parameters affected by these changes is the surface wettability, i.e. the degree at which the surface is wet. The wettability regime of a surface can be defined based on the the contact angle (θ) of a sessile drop resting on the surface. For a contact angle bigger than 150° the surface is called superhydrophobic while for a contact angle lower than 10° it’s called superhydrophilic. In between the terms hydrophobic and hydrophilic are used with 90° as the dividing value. The effect of wettability on pool boiling heat transfer has been the subject of many studies but it is yet to be fully understood. Moreover, only recently some authors started to point out that it is important to separate the effects of wettability and topography on pool boiling [1].

A previous work [2] has been carried out where the behaviour of superhydrophobic and hydrophilic surfaces was studied. This study included the complete description of heat transfer, through the reconstruction of the boiling curve, as well as bubble dynamics, through the analysis of high-speed images and quantification of relevant parameters.

In the present work, the same methodology was adopted enlarging the study to superhydrophilic and the so-called biphilic surfaces, which in this case possess superhydrophobic spots surrounded by hydrophilic ones.

Biphilic surfaces are thought to join the advantages of superhydrophobic and hydrophilic surfaces as suggested by [3], [4] or [5]. The fact that superhydrophobic surfaces need lower superheat for onset of nucleate boiling (ONB), [6], makes them perform better at lower heat fluxes. However, at the extreme, when dealing...
with superhydrophobic surfaces they tend to form an insulating vapor layer that triggers earlier critical heat flux (CHF), [2] and [1]. Hydrophilic promote wetting and thus tend to have a higher CHF [7].

Few studies have been made on biphilic surfaces, ([3], [8], [9], [10], [5] and [11]. The later focused specifically on single bubble dynamics.

In this study three patterns were developed with varying dimensions of the superhydrophobic spots. The relation between pitch and diameter was kept constant and equal to 1.

2 – Experimental Method

2.1 – Experimental Setup

A schematic of the experimental setup is represented in Figure 1. In the middle of the schematic the chamber is seen represent by the blue square. It is a 40x40x40 mm cube made of aluminium with side windows to allow for high speed videos to be recorded. They are recorded with a high speed camera (Phantom 640). A 50 Watts pure white LED is placed on the opposite side of the chamber to provide contrast.

The chamber features a pressure transducer (OMEGADYNE), two thermocouples (type K), internal resistances with a PID controller and two external resistances on the sides of the chamber controlled by a rheostat. The pressure transducer gives feedback of the pressure inside the chamber which is then adjusted through the opening and closing of two electro valves (one for the outflow and another for the inflow). The PID controls the internal resistances keeping the temperature at saturation level while the external resistances minimize the losses.

The surface to be tested is fixed to the heating block. The heating block is hollow to allow for a heating cylinder to pass through it and heat the surface. Between the surface and the heating cylinder is where the heat flux sensor and type T thermocouple are placed. Both are fabricated and assembled by Captec Enterprise.

Two reservoirs, represented as one in Figure 1, are dedicated to the degasification of the distilled water i.e. the removal of gas such as $O_2$ or $N_2$, dissolved in the water. It is the first step in the experimental procedure, affecting the working conditions if not carried out properly, and consequently, the experimental results.

The DATATRANSLATION (DT) DAQ board (DT9828) is where the thermocouples connect to. The board is then connected to the computer where the values are recorded. On the other hand, the heat flux sensor and electro valves signals go through a NI BNC-2120 acquisition board, where the signals are amplified and transmitted to a LabVIEW routine. The boards are represented as one in Figure 1 (DAQ).
2.2 – Experimental procedure

**Surface preparation**

Two main types of coatings, biphilic and superhydrophilic, were prepared and tested. Both have the same substrate which consists of a 1 mm thick stainless steel plat.

Before fabricating and testing the surfaces, a cleaning procedure was employed to ensure that the coatings would stick properly to the surface. The process is done by immersion in acetone on ultrasound bath for 30 minutes followed by drying. This is then repeated with distilled water.

For biphilic surfaces a chemical coating (Glaco) was applied which gives the surface superhydrophobic properties. Since the product is a spray, it was necessary to develop a matrix that would allow the spray to be only applied in some spots. The matrix had the intended sizes of the superhydrophobic spots. The characteristics of each of the biphilic surfaces are presented on Table 1. Schematics are depicted on Figure 2 and the heating cylinder fits in the circumference in the centre. The coating was applied three times with a 24-hour interval between each.

**Table 1 – Characteristics of biphilic surfaces**

<table>
<thead>
<tr>
<th>Denomination</th>
<th>Spot dimension [mm]</th>
<th>Pitch [mm]</th>
<th>Number of Spots</th>
</tr>
</thead>
<tbody>
<tr>
<td>B10</td>
<td>10</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>B05</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>B02</td>
<td>2</td>
<td>2</td>
<td>9</td>
</tr>
</tbody>
</table>

Superhydrophilic these surfaces were prepared at IST at Laboratório de Electroquímica (Laboratory of Electrochemistry). The method applied was hydrogen temple which consists in an electrodeposition at high currents that generates hydrogen bubbles.

**Surface Characterization**

Contact angles and roughness parameters were measured before and after the experiments. The advancing and receding contact angles were measured. An optical tensiometer was used, which captures on video the deposition of a sessile drop with 5 μl volume analysing it afterwards with its own algorithm based on Young-Laplace equation.

![Figure 2 - Patterns of biphilic surfaces. Circumference represents limit of heating area.](image)

Surface roughness was evaluated qualitatively and quantitatively. The former is done through the confocal microscope while the latter using a profile meter (Dektak 3 from Veeco) allowing for the calculation of $R_a$ and $R_z$. Table 2 presents the characterization parameters for all the surfaces and the bare substrate.

**Pool boiling tests**

Figure 3 shows a flowchart with the main steps from test preparation until the very end of it.

**Table 2 – Characterization parameters of all surfaces**

<table>
<thead>
<tr>
<th>Surface</th>
<th>$\theta_{adv}$ [°]</th>
<th>$\theta_{rec}$ [°]</th>
<th>Hysteresis [°]</th>
<th>$R_a$ [μm]</th>
<th>$R_z$ [μm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>B10</td>
<td>166,2</td>
<td>164,3</td>
<td>1,9</td>
<td>0,09</td>
<td>0,13</td>
</tr>
<tr>
<td>B05</td>
<td>165,8</td>
<td>164,9</td>
<td>0,9</td>
<td>0,09</td>
<td>0,13</td>
</tr>
<tr>
<td>B02</td>
<td>160,7</td>
<td>159,4</td>
<td>1,3</td>
<td>0,09</td>
<td>0,13</td>
</tr>
<tr>
<td>SHF</td>
<td>≈ 0</td>
<td>N/A</td>
<td>N/A</td>
<td>2,97</td>
<td>3,48</td>
</tr>
<tr>
<td>Substrate</td>
<td>87</td>
<td>N/A</td>
<td>N/A</td>
<td>0,09</td>
<td>0,13</td>
</tr>
</tbody>
</table>
3 – Results and discussion

Two main analysis approaches were followed. One concerning the performance of the surfaces, through pool boiling curves, and the other concerning bubble dynamics, through the analysis, by a MATLAB routine developed by [2], of the high speed video analysis. Target parameters include: bubble diameter, contact angle and contact line velocity.

Figure 4 shows the boiling curves for all the tested surfaces and also for those tested by [2]. In this figure Spho and Sphi refers to the superhydrophilic surface and superhydrophobic, respectively. From previous works, mainly [9] and [11], it was expected that biphilic surfaces would perform better than the hydrophilic. For all the biphilic surfaces this was confirmed. Nevertheless, the one with more superhydrophobic spots (of smaller size), B02, has a lower heat flux than the hydrophilic for wall superheat higher than 30 K. This may be due to the high number of nucleation spots close to one another that will increase interference between bubble. This interference can make it harder for a bubble to be release and therefore spoil heat transfer.

It was observed that the biphilic surfaces have an onset of nucleate boiling at much lower superheat than the hydrophilic surface. While hydrophilic surfaces have ONB at 12 K superheat, the biphilic have a ONB at about 1-2 K, typical values for the superhydrophobic surfaces. This is a big advantage since in this region the hydrophilic surface is still exchanging heat through natural convection while the biphilic are already in pool boiling. On the other hand, the superhydrophobic surfaces have a high heat resistance across the vapor blanket and prevent high heat fluxes to be reached. Biphilic surfaces prevent this from happening due to the wettability contrast at the border of the superhydrophobic spots. It is well seen on Figure 5 that the bubble stays confined to the hydrophobic dots. This is line to that observed by [3], [11] or [5]. It is because of this that, at this low superheat, biphilic surfaces have a higher heat transfer coefficient.

The evolution of the boiling curve for the biphilic surfaces is similar to the superhydrophobic surface (with a different slope). Instead of an initial region with lower slope and a later with higher slope, like the hydrophilic, it follows almost a straight line. This is because the heat transfer mechanisms don’t change significantly throughout the experiments.
Figure 4 – Pool boiling curves for tested surfaces and those from [2]

Figure 5 – Bubble confined to superhydrophobic spots. From left to right: B10 at 1 K superheat, B05 at 2 K superheat and B02 at 6 K superheat.

When moving to higher wall superheat, bubbles would start to nucleate in interface between the two regions of different wettability and after at the hydrophilic area.

The bubbles at interface normally appeared at about 5 K superheat for the B10 and 7 K for the B05 and B02. Most of this bubbles would grow until their interface was close enough to the superhydrophobic bubble to merge with it (Figure 6). On the case of the B02 and B05 this promoted the release of the superhydrophobic bubble since its diameter is closer to the bubbles on the interface. When they would merge, the impulsion forces on the superhydrophobic bubble would immediately increase and surpass the surface tension. On the B10 surface this did not happen since the bubbles that merged with the superhydrophobic were not large enough to increase dramatically the impulsion forces. The bubble would then grow faster than in the first points but the difference was not as big as for the B05 and B02.

The bubbles on the hydrophilic area would appear for the B02 at 20 K superheat, for the B05 at 12 K superheat and for the B10 at 16 K superheat. This values are consistent with the superheat necessary for a hydrophilic surface with uniform wettability. Nevertheless, the B02 and B10 surfaces need a higher surface temperature. On the B10 case this is probably due to the fact that the superhydrophobic spot occupies most of the heating area leaving less area for the hydrophilic bubbles to nucleate.

Figure 6 – Bubbles of the interface merging and departure of the superhydrophobic bubble. On top B10 surface and on the bottom B05

A consequence of the bubbles being confined on the superhydrophobic spots is that it is possible to control its departure diameter. It can be seen from Figure 7 that depending on the size of the dots the bubble departure diameter assumes a steady value. The larger the dot the larger the departing diameter of the superhydrophobic bubble.
For the 5 mm spots (B05) and the 2 mm spots (B02) there is no clear change in the diameter with increasing heat flux. The 10 mm spot (B10) starts with a lower departure diameter that steadily rises until it reaches a constant value at higher heat flux. Only from the third point onward is that the base of the bubble coalesces with smaller bubbles that were nucleating right next to the contact line and reaches its full dimension.

On Figure 8 bubble departure frequency is presented for the B05, B10 surfaces and for the hydrophilic and superhydrophobic surfaces tested by [2]. B02 values are omitted since they have a big error due to the big amount of bubbles present. For the biphilic surfaces only the frequency for the superhydrophobic bubble is presented. The frequency for the superhydrophobic bubble for the B10 surface follows a steady increase. As discussed before this is due not only to the increase in surface temperature (which increases the vaporization rate) but also to the merge of the smaller bubbles on the interface with the big superhydrophobic one.

For the B05 surface an initial decrease in bubble departure frequency is observed followed by a steady increase. To understand why the initial drop, the frequency for the superhydrophobic and hydrophilic bubbles on the biphilic surface was plotted on Figure 9. In this context, hydrophilic bubbles refers to all the bubbles released that did not coalesce with the superhydrophobic bubble, i.e. the actually hydrophilic bubbles plus the ones that nucleate on the border of the spot but end up not merging with the superhydrophobic one. It is clear the drop in the frequency of the superhydrophobic bubble is accompanied by the very rapid rise of frequency for the other bubbles on the surface.

The frequency of this bubbles goes from about 15 Hz to about 200 Hz. Moving up the heat flux there is another drop of frequency. At this point it is not possible anymore to estimate bubble frequency for the same reason that it was not estimated for the B02 surface. However, it is supposed that either the frequency of the hydrophilic surfaces rose again very rapidly or that the moment captured on video had specific interaction between bubbles (such as less small bubbles merging into the superhydrophobic) that slowed the frequency of the superhydrophobic bubbles. Because the frequency drop was not as big as the first one it is more likely that the latter is true.

It should be noted, from Figure 8, that the frequency of bubble from the superhydrophobic spots follows a trend much more similar to the full superhydrophobic surface than to the hydrophilic. This was also observed for the boiling curves as discussed in the beginning of the chapter.

Figure 10, Figure 11 and Figure 12 show the evolution of a bubble on the superhydrophobic spot for the B02 surface at 5 K superheat, the B05 surface at 3 K superheat and for the B02 surface at 2 K superheat. Looking at the last image of each of the figures it is possible to see one the distinct features of the biphilic surfaces. As pointed out in the beginning the superhydrophobic surfaces form an insulating vapor blanket across the whole surface. The biphilic surfaces also show a similar phenomenon. When the bubble that is confined to the superhydrophobic spot departs, it leaves behind, attached to the surface, the base of the bubble. The difference to the superhydrophobic surface is that this portion of vapor doesn’t
spread across the surface staying confined to the spot itself. A new bubble will then start to grow from the same place.

![Figure 9 – Bubble departure frequency as a function of heat flux for biphilic surfaces.](image)

Regarding the diameter evolution, shown on Figure 13, the bigger the square the more time the bubble takes to depart. As mentioned it is not possible to record the whole bubble cycle for the B10 surface at this superheat. However, one can see from the graph that this was the one with the longer growth time of the three biphilic surfaces. The B02 and B05 surfaces display a similar progression of the diameter though the B05 reaches a higher value. This should be because the spots of the B05 are bigger which increases the forces that keep it on the surface. As such a higher impulsion force is necessary for the bubble to detach and consequently a larger volume of vapor.

![Figure 10 – B02 superhydrophobic bubble growth at 5 K superheat](image)

![Figure 11 – B05 superhydrophobic bubble growth at 3 K superheat](image)

![Figure 12 – B10 superhydrophobic bubble growth at 2 K superheat](image)

After the bubble grows enough for the bubble diameter to surpass the bubble base diameter it starts to elongate vertically.

When the impulsion forces are big enough the bubble starts to detach and on the base of the bubble a phenomena called bubble necking takes place. This can be seen on the bubble growth figures displayed above. This behaviour is in line with that observed by [11].

Figure 14 shows the temporal change in contact angle during bubble growth. This contact angle is measured on the vapor side of the bubble. From Figure 14 it is seen that the bubbles nucleating in the superhydrophobic spots the B02 and B05 follow a slightly different trend from the ones nucleating on the B10 surface. However, they all display the same behaviour just
before the bubble detaches. The contact angle drops from a previous constant value to a value closer to the superhydrophobic one. This is explained by the bubble necking phenomena. For the B02 and B05 surface the contact angle drops from above 90˚ to below 90˚. This means that the force that keeps the bubble on the surface changes the direction and starts point away from the bubble axis keeping the contact line stuck on the spot border. This change in force directions was recently reported by [12].

Figure 13 – Bubble diameter temporal evolution.

On the other end, when the bubble started to grow on the B02 and B05 surfaces, the angle recovered from the lower contact angle to the mentioned constant value. This was an average of 113˚ for the B05 and 122˚ for the B02. Only for the B10 this would not happen. The value never went above 90˚ in this case showing a behaviour more similar to a superhydrophobic surface. This can be due to the fact that the area of the spot is big enough to cover a big portion of the heating area (31,8 %). Also the size of the spot being this big might attenuate the effects of the wettability change on the bubble itself.

Figure 15 shows the contact line velocity of the hydrophobic bubble. It indicates if the contact line is moving and how much it is moving. To compare the values gathered it is plotted together with the superhydrophobic surface tested by [2]. The small variations on the biphilic surfaces are due to detection errors. This further confirms the fact that the contact line is pinned at the border of the superhydrophobic spot. Returning to the pool boiling curves, of Figure 4, first presented on this chapter and keeping in mind the bubble dynamics analysis performed, some suppositions can be made. While the B10 surface has hydrophobic bubbles with a higher diameter than the B05 the frequency of the later is bigger. Also the hydrophilic bubble frequency is higher on the B05 than on the B10 surface with similar departure diameters. However, the B10, as shown by the boiling curves, is able to reach higher heat fluxes for the same superheat. [13] refers that the vaporization rate accounts for no more than 25% of total heat transfer while the rest is due to transient conduction enhanced by the rewetting regime and break-up of the superheated layer close to the wall. On uniform superhydrophobic surfaces these last two mechanisms are drastically reduced due to the insulating vapor layer and latent heat accounts for almost all the total heat transferred as shown by [2].
cause a bigger gap on the superheated liquid layer. The B05 at higher heat fluxes starts to have a lot of hydrophilic bubbles around the hydrophobic that may spoil this effect. To check this, a simple estimation for the vaporization rate and latent heat was made for the first points of the boiling curve of these two surfaces. The departure frequency of the hydrophobic and hydrophilic bubbles and the correspondent diameter was used with the latent heat of vaporization and vapor density at atmospheric pressure to make this calculation. Then it was compared to the total heat flux measured during the experiments. These estimates are presented on Table 3. As it was expected the vaporization rate increases with increasing heat flux and as the latent heat is directly proportional to the vaporization rate it also increases. It is interesting to notice that for the B05 surface the fraction of total heat respective to the latent heat increases from the first point to the second which, as seen on Figure 9 it is when the hydrophilic bubbles increase drastically its frequency. After this it decreases slightly. For the B10 the latent heat share of total heat reduces from the first point to the second and then increases slightly.

This results support what was hypothesized about the rewetting mechanism. The parcel corresponding to transient conduction (enhanced by the rewetting and break of the superheated liquid layer), for the same superheat is bigger on the B10 than on the B05 (comparing first point of B05 with last of B10). On the same two point the vaporization rate is also bigger on the B10 and accounts for a bigger share of the total heat. This might be the area covered by the superhydrophobic spot, bigger on the B10 than on the B05.

A superhydrophilic surface was tested with the intention of complementing the biphilic surfaces tested here and the hydrophilic and hydrophobic surfaces tested by [2]. The boiling curve is shown together with the ones from the other surfaces on Figure 4. The boiling curve shows that it follows the hydrophilic trend until 25 K where it starts performing worse. One problem arose from the experiment of this surface. The actual superhydrophilic area was smaller than the heating area. This means that two areas of different wettability will be subject to boiling. The bubbles started to nucleate, at 16 K superheat, right in the border of the superhydrophilic area.

This results support what was hypothesized about the rewetting mechanism. The parcel corresponding to transient conduction (enhanced by the rewetting and break of the superheated liquid layer), for the same superheat is bigger on the B10 than on the B05 (comparing first point of B05 with last of B10). On the same two point the vaporization rate is also bigger on the B10 and accounts for a bigger share of the total heat. This might be the area covered by the superhydrophobic spot, bigger on the B10 than on the B05.

### Table 3 – Estimation of latent heat and total heat of the B05 and B10 surfaces

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.409E-3</td>
<td>0.294</td>
<td>1.250</td>
<td>0.235</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1.304E-3</td>
<td>0.937</td>
<td>2.243</td>
<td>0.418</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1.618E-3</td>
<td>1.162</td>
<td>3.0518</td>
<td>0.381</td>
<td></td>
</tr>
<tr>
<td>B10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.640E-3</td>
<td>0.459</td>
<td>0.762</td>
<td>0.603</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.595E-3</td>
<td>0.427</td>
<td>1.278</td>
<td>0.334</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.311E-3</td>
<td>0.942</td>
<td>2.41</td>
<td>0.391</td>
<td></td>
</tr>
</tbody>
</table>

4 – Conclusions

Biphilic surfaces with different patterns were fabricated and tested under pool boiling. The patterns consisted of superhydrophobic squares surrounded by hydrophilic areas. The relation between diameter and pitch was constant and equal to 1. The dimension of the spots was 2 mm (B02), 5 mm (B05) and 10 mm (B10). Bubble dynamics parameters (bubble diameter, contact angle and contact line velocity) were measured with the help of a high speed camera and a post-processing routine previously developed in MATLAB.

A peculiar behaviour of the biphilic surfaces was observed when compared to hydrophilic and superhydrophobic surfaces. The onset of nucleation was at similar wall superheat than the superhydrophobic surfaces, 1-2 K. However contrary to the superhydrophobic the biphilic would not get entirely covered with an insulating vapor blanket. The wettability contrast on the border of the spots would prevent the vapor from moving further than the border itself. It is supposed that the heat transferred through transient conduction when a bubble departs and breaks the superheated layer plays a big part here. Compared to the hydrophilic surface they would also perform better. This was mainly due to the fact that nucleation on the hydrophilic surfaces starts at a higher heat flux, 12 K. Through the boiling curve it is observed that the basic heat transfer mechanism seems to be always the same since the line is almost linear. The biphilic pattern that performs better is the B10, then the B05 and the one that performs
worst is the B02. Through the bubble dynamics analysis some of this aspects can be explained. The B10 has the highest bubble departure diameter which associated with its frequency yields the biggest vaporization rate at least when compared to the B05. It is also supposed that the B10 surface has the most efficient rewetting mechanism since this parcel of the total heat transferred is also bigger for this surface. The fact that only one big bubble is present probably makes this mechanism more well organized where the amount of liquid that rewets the surface is bigger and at lower temperature. This would increase the heat transfer rate through transient conduction. It was observed for all the biphilic surfaces that when surface superheat corresponding to ONB of the hydrophilic surfaces was exceeded, bubbled started to nucleate on the border of the spots and later on the hydrophilic part. The bubbles on the border would merge with the superhydrophobic bubbles and decrease its growth time, increasing consequently the frequency. The bubbles had the lowest growth time for the B02 surfaces while on the B10 they took the longest to depart. The contact angle started close to 60° and rose to 113° for the B05 and 122° for the B02. For the B10 surface the contact angle was constant during bubble growth. Just before bubble departure the contact angle would fall again to values below 90°. The contact line is stuck and does not move.

As future work regarding the biphilic surfaces pitch and diameter should be varied independently to infer on its effect on interference and heat transfer mechanisms. Also the dimensions of the spots should be taken to the micrometre scale as some studies report huge increases of heat flux when going to this scales. The superhydrophilic surfaces study should also be completed with description of bubble dynamics and solving of the problem related with insufficient area of superhydrophobic properties. Further system with which images are acquired can be improves incorporating laser illumination. This would allow specific plans to be observed and prevent other bubbles form spoiling the videos. It would allow for the bubble dynamics analysis to be carried out until later stages of the boiling curve.