# A Theoretical Study of High Pressure Pool Boiling Heat Transfer on Engineered Surfaces


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## Abstract

The performance of pool boiling is studied at high pressure on engineered surfaces. The studies were done for two different surfaces i.e., hydrophilic (CA < 90°) and hydrophobic (CA > 90°) surfaces. In addition, the bubble dynamics on a biphilic surface is also presented. Previous results are shown that the hydrophobic surfaces promote bubble nucleation at a lower super heat due to low surface energy is required. However, the effect of high pressure is sill need to be studied. The parametric studies were done for the size of active nucleation sites, departing bubbles and bubble release frequency under the influence of pressure. The current study will explain how the bubble dynamics affect the performance of boiling heat transfer.


## Introduction

The pressure has a huge impact on the boiling performance. Water boils faster at high pressure due to change in the properties of water.

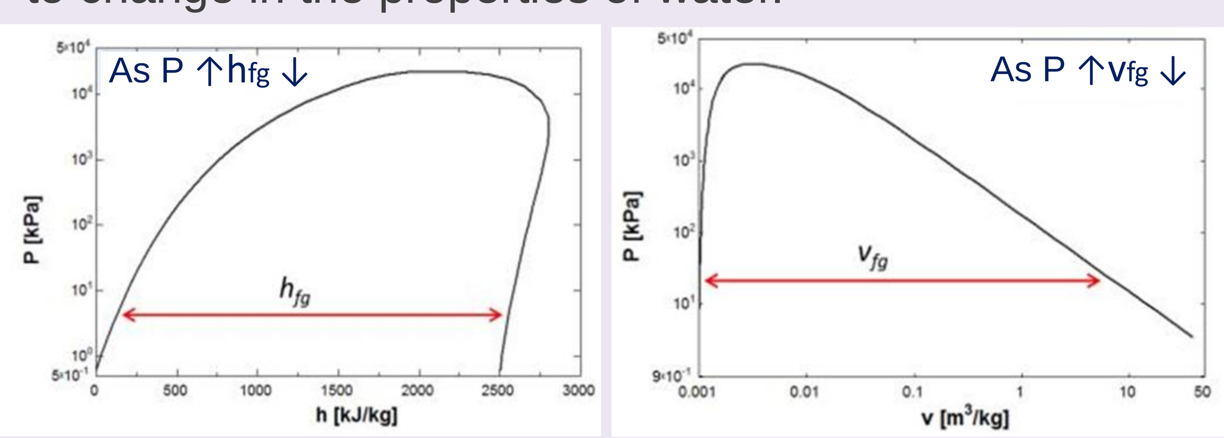



Fig 1. Effect of pressure on the latent heat of vaporization and the specific volume. As pressure increases, the change in enthalpy and the specific volume of water decreases. [3]

In 1962, Hsu reported that the boiling initiates from the cavities or defects present on the surface called nucleation sites [1].

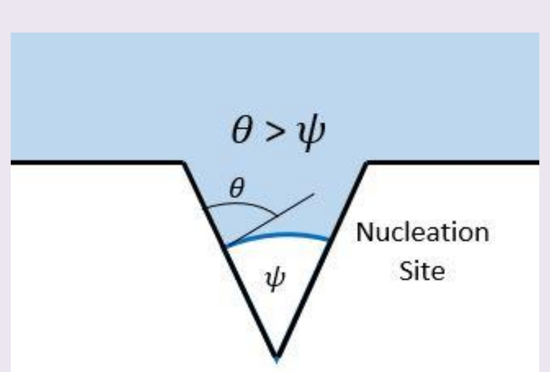



Fig 2. A schematic of cavity entraps gas/vapor on the surface. The angle $\theta$ and $\psi$ represent the contact angle and cavity angle respectively.

Mikic and Rohsenow Model [2]

$$\mathrm{HTC} = 2(\Pi k_l \rho_l c_{pl})^{1/2} \eta_a {d_d}^2 f^{1/2}$$

$k_l$ is the thermal conductivity of the liquid
$\rho_l$ is the density of the liquid phase
f is the bubble frequency
$n_a$ is the active nucleation site
$c_{pl}$ is the heat capacity of the liquid phase

## What is Biphilic surfaces?

The juxtaposition of hydrophilic and hydrophobic regions are called "Biphilic" surfaces [5]

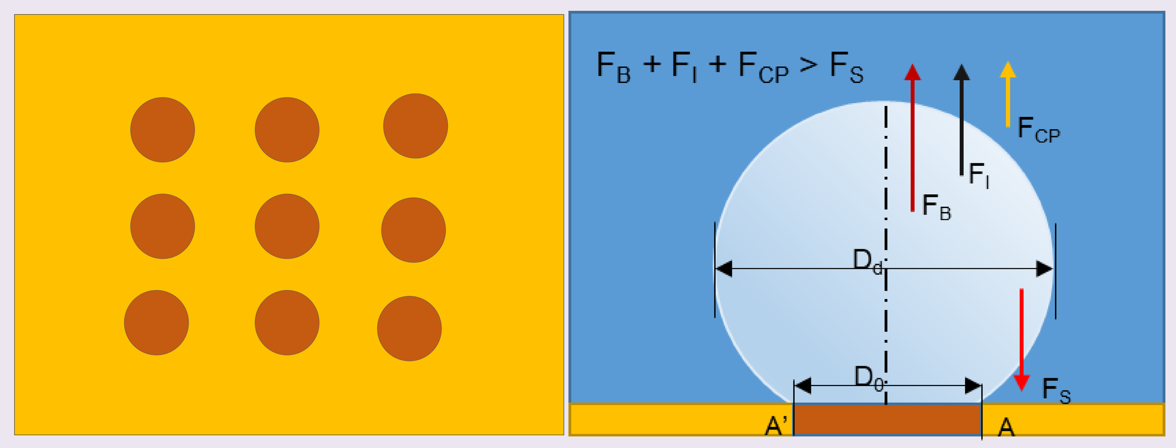
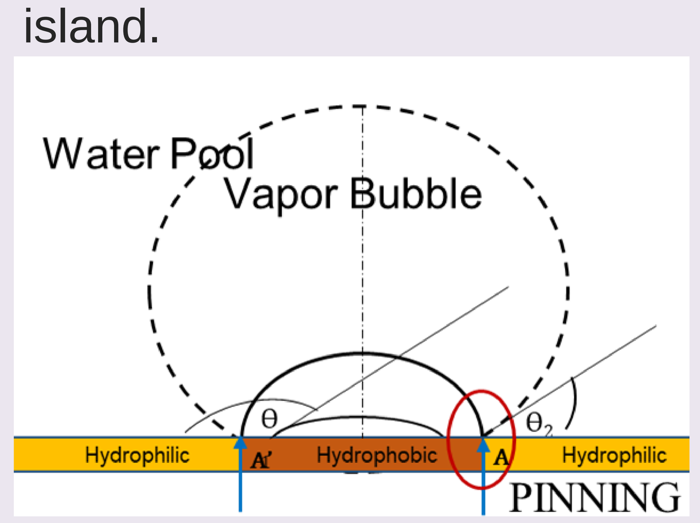



Fig 3. Force balance of a spherical vapor bubble sitting on a biphilic surface. The patterned surface is designed with hydrophobic surface on a hydrophilic island.




Pinning Mechanism: Bubble Pins at the edge of hydrophilic and hydrophobic surface

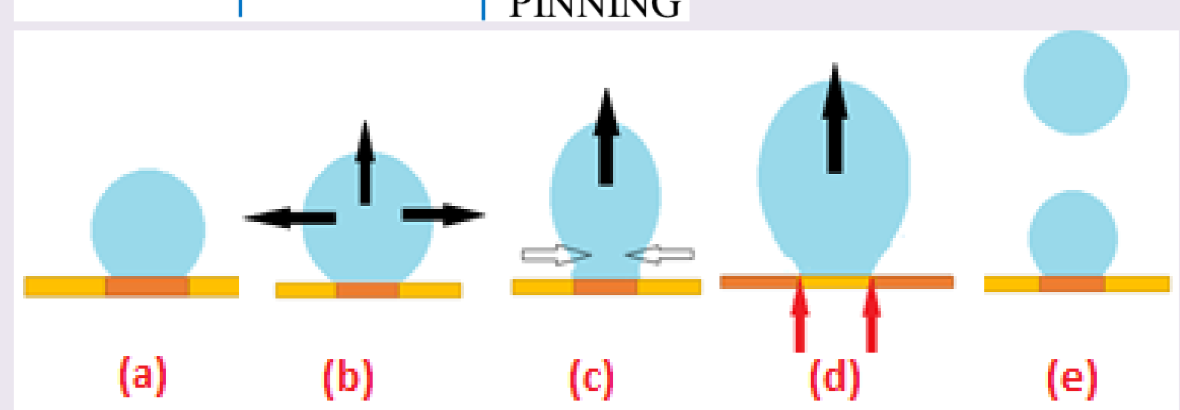
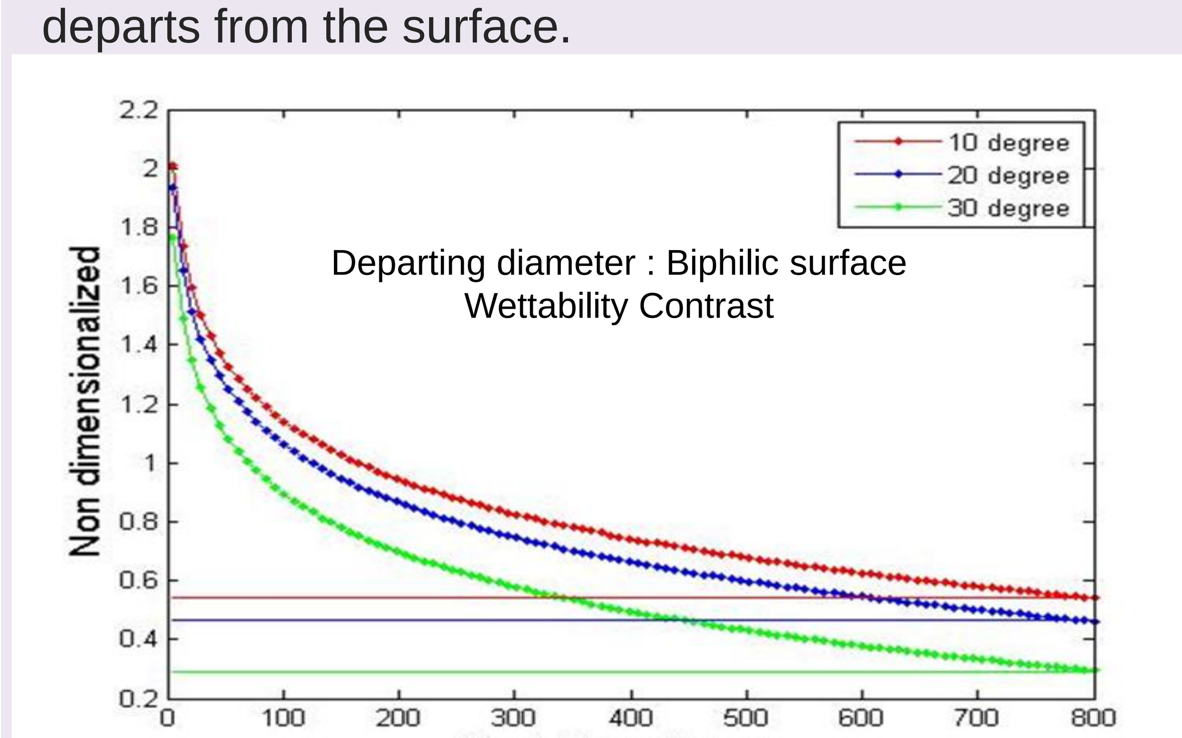
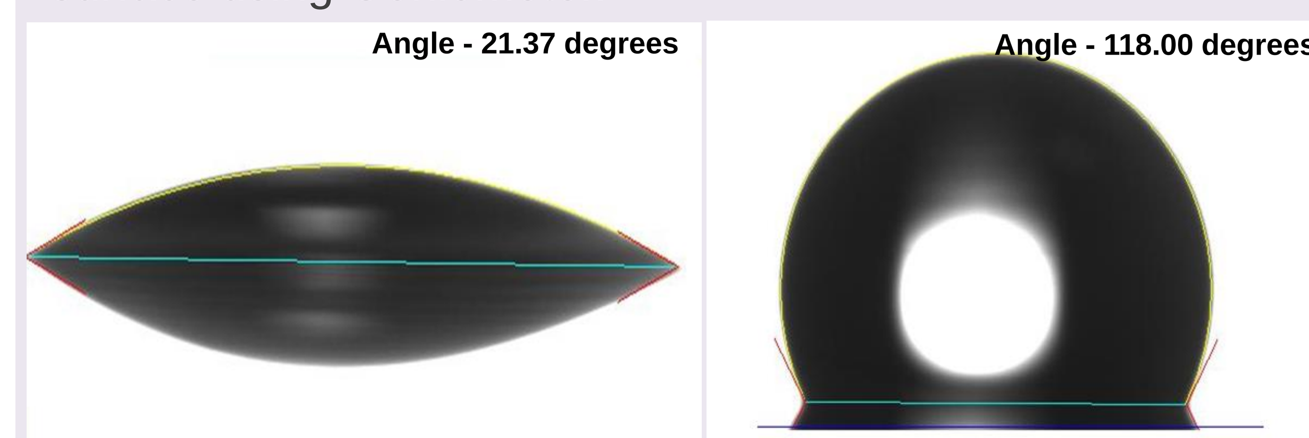



Fig 4. Evolution of bubble from a biphilic surface is shown in the above picture. Bubble starts nucleating from the hydrophobic surface. As the surface temperature increases the bubble gets enlarge and starts pinning at the edge of hydrophilic surface and pulls back toward the surface. When the buoyant force exceeds the surface tension of the liquid, the bubble departs from the surface.

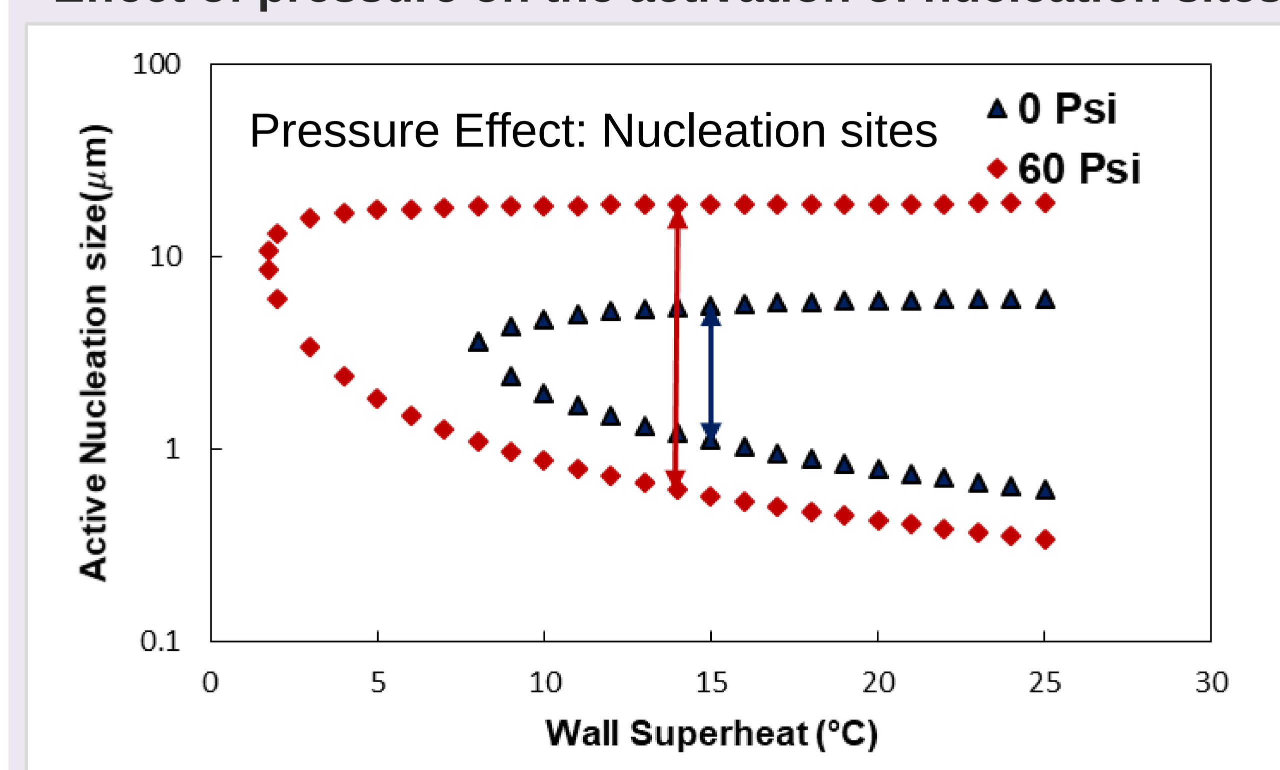



## Results

Measured contact angle on a hydrophilic and hydrophobic surface using Goniometer.

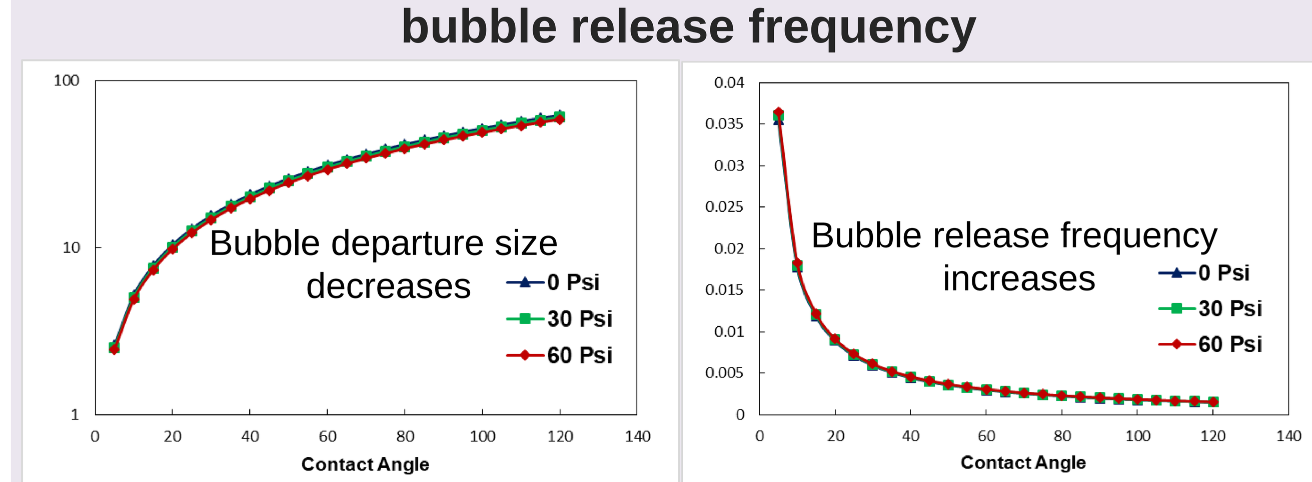



**Effect of pressure on the activation of nucleation sites**

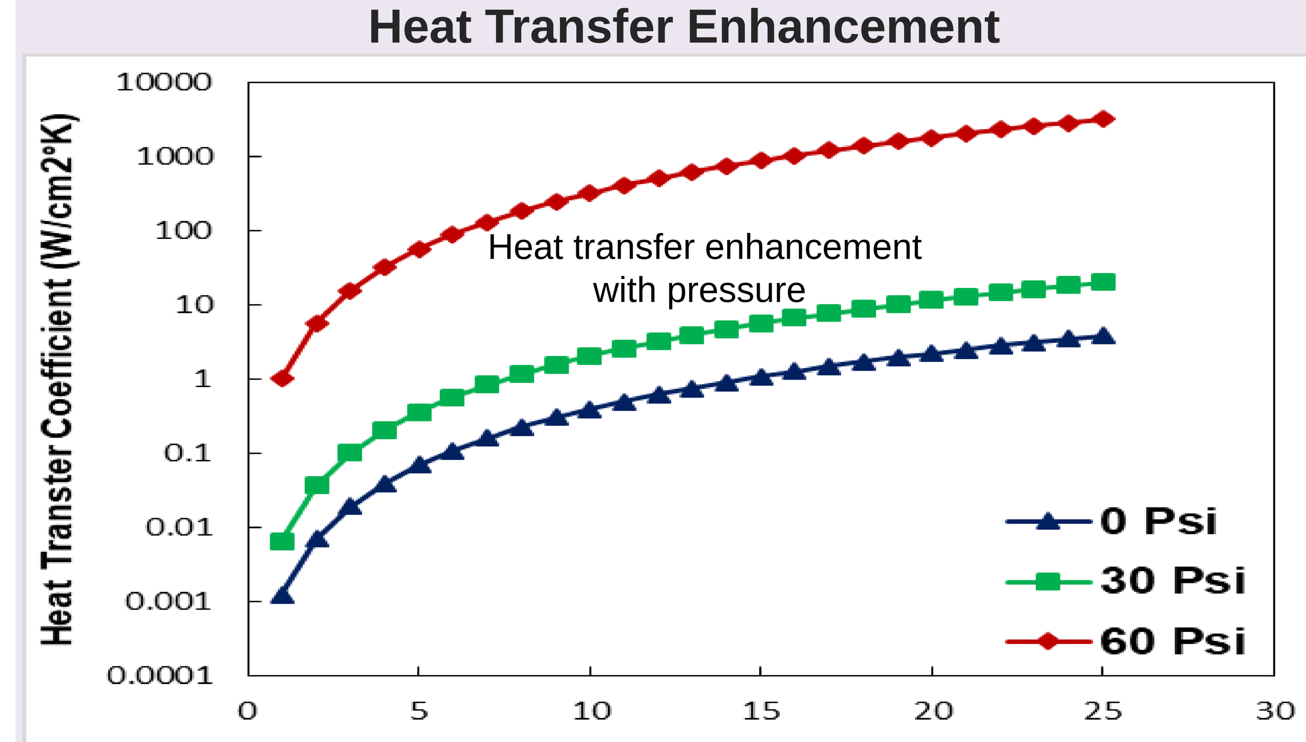



1. Nucleation sites activate at a low wall superheat
2. It widens the size range of nucleation sites

**Effect of pressure on the size of bubble departure and bubble release frequency**




**Heat Transfer Enhancement**




## Conclusion

In this study, the effect of pressure on the performance of pool boiling is predicted for engineered surfaces. The parametric studies are done for the size of departure diameter, range of active nucleation sites, bubble release frequency and the heat transfer coefficient. The results reveal the physical mechanisms of pool boiling heat transfer for the combined effect of system pressure and surface wettability. The nucleation sites activate at a low wall superheats when the system gets pressurized. The vapor phase change on a Biphilic surface has been discussed.

## Future Work

1. Experimental data of high pressure is required to validate these theoretical results.
2. High pressure pool boiling experiment will be studied on different nano-engineered surfaces.
3. The present model could be validated by performing pool boiling experiments on new biphilic surfaces.
4. The performance of flow boiling on biphilic surfaces could be analyzed in future for micro channels.

## References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