BUBBLE NUCLEATION DYNAMICS OF R-134A REFRIGERANT IN A POOL BOILING SYSTEM

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Introduction: Although boiling is a complex and elusive process, it is one of the most effective means of heat transfer in various energy conversion and heat exchange systems as well as cooling of high energy-density electronic components. The importance of nucleate pool boiling arises from its ability to remove significant amount of heat per unit time and area from hot surfaces with relatively low temperature difference. Nucleate pool boiling involves many processes and complexity of this boiling originates from bubble nucleation and interactions that occurs between the wall and fluid.

In pool boiling heat transfer particularly in a pressurized environment, it is difficult to precisely determine the heater surface temperature at any specific bubble nucleation site which is a very small region of interest (i.e. microscale region). Accurate measurement of the wall temperature is challenging because this temperature varies temporally and spatially [1]. In order to understand bubble characteristics in pool boiling, it is important to determine the temperature mapping around the nucleation site. However, thermocouple usage in such small regions is not practical for temperature mapping of heater surface since the device would impede the bubbling events. Thus, finding alternative and non-invasive techniques for precise measurement of heater surface temperature in boiling heat transfer systems is essential. An innovative technique which is to apply the thermochromic liquid crystals (TLC) to determine the wall temperature over a surface area of interest is employed in this study.

Liquid crystal thermography offers numerous advantages compared to commonly used temperature sensors such as thermocouples or resistance thermometers [2-6]. When dealing with microregion applications, such sensors can be intrusive to the physical phenomenon (e.g. bubble nucleation) to be investigated. On the other hand, TLC is a non-intrusive and most suitable tool for such applications. Other important advantages of using TLC are the extensive nature of the temperature measurements compared to a few spot measurements using thermocouple and the absence of disturbance to the microgeometry and wettability of the boiling surface. TLC also enables measurement of two-dimensional temperature distribution on any micro-or macro region of boiling surface with very small spatial resolution.

This study reports heat transfer and bubbling characteristics of refrigerant R-134a in a pressurized pool boiling system with the application of TLC technique.

Experimental: A robust test section was designed and built to withstand high pressure and to provide a thermochromatic heating surface. The entire test facility is consists of two major parts: condenser loop and pressurized loop. Main test section is in the pressurized test chamber where the boiling takes place. Supply lines are connected to the test chamber for making up the flow circuit, which provides the constant pressure and temperature conditions. The refrigeration circuit consisted of a positive displacement pump to generate the pressure within the test section. In order to control the pressure a pressure regulator was used to bypass the fluid entering the test chamber. The refrigerant was cooled using a water cooled condenser. Two high resolution and high shutter speed cameras were employed to capture bubble dynamics of present pool boiling experiments.

The thermochromic liquid crystal technique is employed to obtain high resolution and accurate heater surface temperature measurements. In order to use TLC for temperature measurement, hue versus temperature relationship is first established through *in-situ* calibration.The hue values were obtained using customized GUI software. This calibrated relation between hue and temperature is then used to determine the temperature data from RGB images of TLC for experimental runs.

Results and discussion: Heat flux versus wall superheat results for two pressures are depicted in Figure 1(a) which provides the well known linear region in the nucleate boiling regime for R-134a refrigerant. Pressure was also found to have influence on the boiling characteristics as shown in Figure 1(a). The bubble frequency was recorded at different heat fluxes. There was strong correlation between heat flux and bubble generation rate (frequency). Figure 1 (b) shows that the bubble frequency is linearly proportional to the heat flux, within range of 2500W/m^2 to 5000W/m^2. It is found that the system pressure affects the bubble dynamics. For example, an increase in pressure increases the bubble frequency. There was also a decrease in the bubble size with increasing pressure.

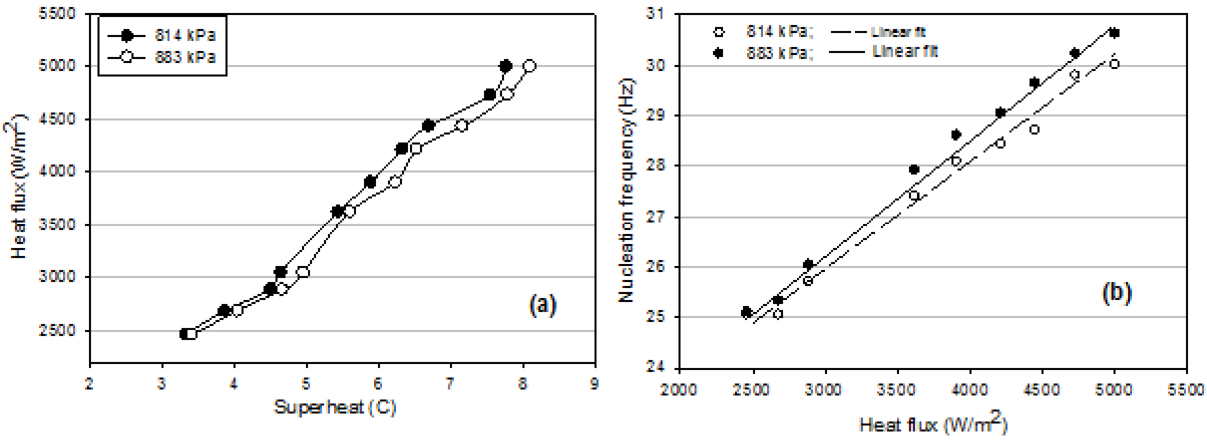

Figure 1. (a) Superheat versus heat flux and (b) heat flux dependence of nucleation generation rate for two pressures.

Conclusions: Applying thermochromic liquid crystal (TLC) technique experiments have been performed to investigate pool boiling and associated bubble characteristics of refrigerant R-134a in a pressurized environment. Effects of heat flux and system pressure on the bubble nucleation and boiling phenomena are studied and results showed that both the heat flux and pressure significantly influence the bubble nucleation and bubbling activities and thus the boiling characteristics. A strong correlation (linear) between heat flux and bubble generation rate was also established from this study.

References:

1. L.S. Tong and Y.S. Tang, *Boiling heat transfer and two-phase flow*, Taylor & Francis Inc., Washington, D.C, 1997.
2. D.B.R. Kenning and Y. Yan, Pool boiling heat transfer on a thin plate: features revealed by liquid crystal thermography, *International Journal of Heat and Mass Transfer* 39 (1996) 3117-3137.
3. D.B.R. Kenning, T. Kono and M. Wienecke, Investigation of boiling heat transfer by liquid crystal thermography, *Experimental Thermal and Fluid Science* 25 (2001)219-229.
4. C. Hohmann and P. Stephan, Microscale temperature measurement at an evaporating liquid meniscus. *Experimental Thermal and Fluid Science* 26(2002)157-162.
5. W. Grassi, D. Testi, D.D. Vista and G. Torelli, Calibration of a sheet of thermosensitive liquid crystals viewed non-orthogonally, *Measurement* 40 (2007) 898-903.
6. J.A. Stasiek, Thermochromic liquid crystals and true colour image processing in heat transfer and fluid-flow research, *Heat and Mass Transfer* 33 (1997) 27-39.