
ABSTRACT

Boiling is a natural phenomenon that is observed in everyday life. It occurs at the interface of a heated surface and a hot liquid. Nucleate boiling is the most desirable regime of boiling where the heat transfer coefficient is very high. That is why it is used in many industrial applications such as steam generation in power plants, preventing overheating in electronic cooling, and thermal desalination in chemical process industries, etc. It enables high heat dissipation at a relatively low wall superheat temperature, a process dominated by rapid bubble formation and intense liquid vaporization. In this case, a large portion of heat energy is transferred to the bulk liquid, which is carried by the bubbles. Therefore, most researchers have focused on understanding the bubble formation mechanism and scope to improve the boiling performance characteristics. There are two basic parameters usually considered by which nucleate boiling performance is evaluated: one is the boiling heat transfer coefficient (BHTC) and the other is the critical heat flux (CHF). The present work mainly focuses on the enhancement of BHTC on a hydrophobic surface. The BHTC can be enhanced by promoting either active nucleation sites or bubbles start forming at a low wall superheat temperature (low ONB).

In this study, pool boiling performances, such as the boiling curve, onset of nucleate boiling (ONB), and nucleate boiling heat transfer coefficient, have been examined on various coated texture surfaces. A thin film coating layer of three different binary oxide nanoparticle combinations ($\text{SiO}_2/\text{TiO}_2$, $\text{TiO}_2/\text{Al}_2\text{O}_3$ and $\text{Al}_2\text{O}_3/\text{SiO}_2$) has been created via electrophoretic deposition on a copper substrate in a water-based binary hybrid nanofluid. For each combination, four different surfaces were prepared by varying the coating duration. As the coating duration changes, surface characteristics

such as morphology, roughness, coating layer thickness, and wettability also change. The morphology and texture of the coated surface depend on the coating materials as well as the coating duration. Surface roughness (Ra) and coating layer thickness increase as the coating duration increases. All coated textured surfaces are hydrophobic in nature, whereas polished copper is hydrophilic.

A series of pool boiling experiments were performed on twelve different textured and polished copper (bare) surfaces in demineralised water at nearly saturation temperature and atmospheric pressure conditions. Experimental results show that bubbles start forming relatively early on hydrophobic textured surfaces, causing the ONB temperature to reduce. On hydrophobic surfaces, the adhesion force is comparatively less, hence less buoyancy force is required at the departure stage, subsequently, and the bubbles' size is smaller than on the hydrophilic (bare) surface. Also, due to increased surface roughness and changes in the textured pattern, nucleation sites increase on the coated surface. Initially, pool boiling characteristics are influenced by wettability, surface roughness, and surface morphology, and enhancement in BHTC is caused by an increase in nucleation sites and departure frequency. When the coating duration increases, roughness and coating layer thickness also increase, which causes a heat transfer deterioration. Due to increased surface roughness, bubble formation starts at a very low wall superheat and starts interacting with the surrounding bubbles, consequently, large bubbles form before the departure, which causes an increase in wall superheat. Also, due to high coating layer thickness, the thermal resistance of the surface increases and heat transfer decreases, consequently, the wall temperature increases.

Experimental investigation revealed that the boiling heat transfer performance of hydrophobic textured coated surfaces increased if the coating thickness was

maintained below an optimum range. If the coating layer thickness is kept higher than the optimum range, BHTC may deteriorate, which will increase the surface temperature, and in some cases, thermal damage may occur due to it. The optimum coating layer thickness in the case of $\text{TiO}_2/\text{SiO}_2$, $\text{TiO}_2/\text{Al}_2\text{O}_3$, and $\text{SiO}_2/\text{Al}_2\text{O}_3$ are $\sim 10\mu\text{m}$, $\sim 16\mu\text{m}$, and $\sim 27\mu\text{m}$, respectively, whereas the maximum enhancements in BHTC are 62%, 63%, and 75%, respectively.