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Literature Review 'Nucleate Pool Boiling Heat Transfer on TiO_2 Nano Coated Surface'

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Abstract - *The enhancement for pool boiling heat transfer of untreated, treated and TiO_2 nanocoated surfaces were investigated by many researchers. The untreated, treated surface and the surfaces having various nanolayer thickness were used for investigation. Nanocoating was done by various method and the emery paper was used for treating the surface. The surfaces were characterized with respect to contact angle, roughness, film thickness. The impact of surface roughness on wettability of surface was described based on the contact angle values. The surface roughness values were obtained by the optical profiler. The experimental data was collected with various heat flux ranges. The enhancement of boiling heat transfer coefficient in nano-structured surfaces was due to Capillary effect, better liquid spreading; enhanced wettability and high density active nucleate site and high rate of bubble emission frequency. This review indicates that all TiO_2 coating surfaces with film thickness in nanometer scale influence the boiling heat transfer coefficient significantly.*

Key Words: **Pool boiling, Nano-coating, Heat transfer coefficient, Critical heat flux, Surface roughness, Contact angle,**

1. INTRODUCTION

The process of changing the phase from liquid to vapour by transferring the heat to liquid is boiling process and transferring the heat from one place to other by change of phase is Boiling Heat Transfer. As this flow of heat transfer is a combination of liquid & vapour phases, we can treat the flow as two-phase flow heat transfer. We are interested to study in two phase flow as because of high heat transfer rate in boiling. Because of this, the researchers are interested in this area to improve the heat transfer performance by nucleation. Nucleate boiling is a very effective heat transfer mechanism due to the high heat transfer associated with the latent heat of vaporization and the increase in convection due to bubble motion. Therefore, it is desirable to operate thermal-fluid systems in the nucleate boiling regime. Nucleate boiling has been recognized as one of the most efficient heat transfer mechanisms. In many engineering applications that require super-high heat transfer rates, nucleate boiling heat transfer is the mode of choice. Boiling heat transfer holds the potential advantage of facilitating the transfer of a large amount of energy over a relatively narrow temperature range with a small weight to power ratio.

For a secure energy future the energy conversion efficiency must be advanced. All types of advanced power devices and high-tech electronic systems ranging from heavy-vehicle engines, computer chips and advanced nuclear reactors depend on efficient thermal energy transport mechanisms to acquire heat input and to reject waste heat for the purpose of achieving higher power density and higher system efficiency. Higher cooling rates can increase energy conversion system efficiency, enable higher power density and also elevate system functionality (for example, higher throughput for rocket engines and higher power density for nuclear reactors). Furthermore, as advanced micro-mechanical, microelectronic, and photonic device technologies have led to ever smaller structures, heat dissipation has become an increasingly important problem that will limit the performance. In fact, due to the lack of a breakthrough in advanced cooling technology, the computer processor speed has reached its limit with conventional cooling and the future of tera-hertz computers is now in doubt.

Correspondingly, higher and higher system operating temperatures and power densities are becoming the goals of future energy systems. Accordingly, researchers are turning to untraditional and modern convective thermal energy transport mechanisms for solutions as the conventional convective heat transfer technologies have reached their limits. The fundamental research on nucleate boiling would unveil the controlling boiling mechanisms such that the next breakthrough in cooling technology, for example using nano fluids and nano surface textures, can be realized. So, fundamental boiling research will directly benefit the high heat flux power and cooling industry, especially for the cooling of electronics and nuclear reactors, by providing new dimensions in modeling and simulation capabilities for engineering design and development.

The proper design of thermal fluid system leads to the enhancement of boiling heat transfer coefficient and critical heat flux. Among all enhancement techniques, surface coating is one on which most of the researchers concentrating due to significant enhancement was observed.

2 LITERATURE REVIEW

2.1 Nanoparticle thin film coating

of Layer by Layer assembled multilayer thin Lee D et al. [1] prepared nanoparticle thin film coating via layer by layer deposition of TiO_2 and SiO_2 nanoparticles. The porosity and chemical composition of the coatings were determined using a simple method that is based on ellipsometry and does not require any assumptions about the refractive indices of the constituent nanoparticles. The presence of nanopores in the coatings results in superhydrophilicity as well as antireflection properties. The superhydrophilicity of contaminated coatings could also be readily recovered and retained after ultraviolet irradiation.

D.Lee, Damali Omaolade, Robert E. Cohen and M.F. Rubner [2] demonstrate that the structure film comprising positively charged TiO_2 and negatively charged SiO_2 nanoparticles can be varied by controlling assembly conditions. The surface charge density of the absorbing nanoparticles and that of the previously adsorbed nanoparticle layers are the crucial factors determining the average bilayer thickness of the films.

Wu et al. [3] in a recent paper reported the results of their pool boiling experiments on 1-μm-thick titanium oxide (TiO_2) and silicon oxide (SiO_2) nanoparticle-coated surfaces. Their results also indicate that the hydro philicity of titanium oxide surface provides higher heat transfer coefficient and CHF values.

2.2 Nucleate pool boiling heat transfer of liquids with nano coated surfaces

Yan et al. [4] developed the novel applications of TiO_2 material in inhibiting the deposits on heat transfer surface and in pool boiling with nano meter surface engineering method. The vapour coating technique is used to prepare the TiO_2 coating on the surface with different layer thickness in nano meter scale. This coated surface is characterized in view of contact angle, surface roughness, Scanning electron Microscopy (SEM) and Atomic force Microscopy (AFM). The accumulation of unwanted deposits on heat transfer surface reduces the efficiency of heat transfer in heat exchangers (in evaporators) with water-vapour flows. Measurements taken for mitigate the fouling by applying surface coatings with low-energy. The TiO_2 coating on the surfaces can avoid the $CaCO_3$ deposition and fouling induction period. Here the film thickness of 80×10^{-9} is approximately 50 times longer than the untreated surface.

Phan et al. [5] analyzed the surface wettability and the adhesion energy in order to understand the effects of a thin layer of TiO_2 nanoparticles deposition on heated surface under pool boiling heat transfer conditions. Because of deposition of nanoparticles on heating surface, the geometry of the surface will be changed. One of the most effective geometric changes is generating large number of nucleation sites, which increases the rate of heat transfer, surface wettability and also the critical heat flux. As compared to a clean surface, the nano coated surface increases the adhesion energy and reduces the number of active nucleation sites.

Phan et al. [6] explored the mechanism of surface coating during nucleate boiling in nanofluids. The nanoparticle layer thickness was estimated by geometric measurement on Field Emission Gun – Scanning Electron Microscope (FEG-SEM) images. The porous layer was formed by the deposition of nanoparticles during the boiling of nanofluids and the thickness of this layer increases with boiling duration and concentration of nanoparticles. The wettability of the surface with a TiO_2 nanoparticle layer is higher as compared with clean surface..

Park et al. [7]we report the first direct observations of the distribution and dynamics of the liquid and vapor phases and triple contact line on nano- and microstructured surfaces during boiling of saturated water using an infrared-based detection technique, DEtection of Phase by Infrared Thermometry (DEPIcT).

Ray et al. [8] studied the Pool boiling heat transfer performance of R134a on TiO_2 Coated TF Surface experimentally. They compared the result with a plain copper surface and observed that the maximum enhancement heat transfer coefficient comes from 200 nm coating thickness of substrate and minimum from 100 nm.

Hu et al. [9] experimentally studied the nucleate pool boiling heat transfer of self-rewetting solution by surface functionalization with TiO_2 nanostructure. According to the experimental phenomenon and mechanism analysis, the surface of the nanotube has a more effective vaporization core, greater roughness, and better wettability to achieve enhanced boiling heat transfer.

Prakash et al. [10] analyzes the present status of nano-modification for enhancing the pool boiling and critically compares the experimental results with the theoretical predictions.

2.3 Nanowire

H.G. Na et al. [11] fabricated TiO_2/SiO_x core shell nanowires by heating Au/TiN/Si substrates. They demonstrated that the thickness of the Au layer needs to be optimized to obtain nanowires. To investigate the effect of the Au coated surface with respect to its thickness, they varied the Au layer thickness in a range of 0-27 nm. They observed that nanowire formation is favoured with a thicker Au layer in the range of 3-9 nm.

XU Jia et al. [12] studied the pool boiling of saturated water on a plain Ti surface and surfaces covered with vertically oriented nanotubes arrays. They observed that the wall super heat on the TiO_2 NTAs was decreased by 11k and both the CHF and HTC of pool boiling on the TiO_2 NTAs were higher than those from boiling on a bare Ti surface. They measured the maximum critical heat flux and heat transfer coefficient as 186.7 w/cm^2 and 6.22 w/cm^2k.

3. CONCLUSIONS

The review ends with a conclusion that to enhance the heat transfer coefficient during nucleate pool boiling heat transfer, TiO_2 nano- coated surface plays a very important role. Studied literatures also showed the various technique of nanocoating. However, the following trends were in general agreement with all researchers:

- The heat transfer coefficient enhancement increases with the increase of TiO_2 nanocoating thickness..
- Nanocoated surface has a more effective vaporization core, greater roughness, and better wettability to achieve enhanced boiling heat transfer.
- TiO_2 nanocoated surface produced a higher apparent contact angle than the clean surface.
- Critical heat flux enhancement depends on the coating pattern and surface microstructure.
- CHF of pool boiling on TiO_2 nanocoated surface is higher than those from boiling on a bare surface.

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