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A Challenge of Lowering Wall Superheating at Onset of Nucleate Boiling

Abstract: Onset of nucleate boiling (ONB) always needs wall superheating, ΔT_{sat}, to activate bubble nucleation sites. In general, $\Delta T_{sat,\,ONB}$ ranges from a few degrees to several tens of degrees depending on the type of fluids, wettability, surface structures and concentration of non-condensable gasses. From a viewpoint of electronic cooling, low $\Delta T_{sat,\,ONB}$ is desirable to avoid thermal damages to electronic chips and to ensure stable boiling heat transfer. We have been studying the effects of wettability and solubility of air on the ONB and obtained some important findings for water. Regarding the wettability effect, hydrophobic area of the surface attracts dissolved air and works as an excellent nucleation site. Therefore, by making use of biphilic surfaces nucleate boiling is significantly enhanced. The boiling performance of biphilic surfaces is of about 7 times larger than that of mirror copper surface. This enhancement technique is very effective in subatmospheric conditions. Presence of both hydrophobicity and dissolved air drastically reduces the $\Delta T_{sat,\,ONB}$. In the case of subcooled boiling, the $\Delta T_{sat,\,ONB}$ sometimes can become negative. We have unveiled the mechanism of early onset of nucleation by making use of a special experimental apparatus so to remove any initial dissolved air from the boiling water.

Challenges in lowering $\Delta T_{sat,\,ONB}$ also concern other fluids. We succeeded to lower the $\Delta T_{sat,\,ONB}$ for ethanol by halloysite nanotube (HNT) coating where ethanol displays contact angles higher than 90°. Nucleate boiling for ethanol is also enhanced on the biphilic surface by about 3 to 4 times when compared with bare copper surface. Our recent challenge is to lower the $\Delta T_{sat,\,ONB}$ and enhance nucleate boiling for HFE7100 by making use of anodized aluminum surface, which has nanopores of 20-200 nm in size. The present talk will also report on some other experimental findings related to this recent study.

Bio: Professor Yasuyuki TAKATA is a Research Professor at International Institute for Carbon-Neutral Energy Research (I2CNER), Kyushu University. He is also Professor Emeritus at Kyushu University and Honorary Professor at the University of Edinburgh. He was a Professor in the Department of Mechanical Engineering, Kyushu University until March 2022. His research interests include two-phase flow and heat transfer, thermophysical properties of hydrogen at ultra-high pressure, micro refrigerator and micro heat transfer device and numerical simulation of thermal and fluid flow. He was the Presidents of Heat Transfer Society of Japan (HTSJ) from 2019 to 2020 and Japan Society of Thermophysical Properties in 2016. He served as the President of the Asian Union of Thermal Science and Engineering (AUTSE) from October 2020 to September 2022. He received numerous awards including the JSME Thermal Engineering Achievement Award in 2010, and ASME ICNMM2018 Outstanding Leadership Award in 2018 and Heat Transfer Society Award for Scientific Contribution in 2022. He is a Council Member of Science Council of Japan since October 2020.